DEPARTMENT OF THE ARMY

CORPS OF ENGINEERS

BEACH EROSION BOARD
OFFICE OF THE CHIEF OF ENGINEERS

PRELIMINARY REPORT: LABORATORY STUDY OF THE EFFECT OF AN UNCONTROLLED INLET ON THE ADJACENT BEACHES

TECHNICAL MEMORANDUM NO. 94

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FOREWORD

Many shore problems are complicated by the existence of a tidal inlet cutting through the shore area and affecting, to some distance on either side of the inlet, the reaction of the shore area to the normally applied littoral forces. The effects of these inlets, and of the general inlet regime, can be large, especially if the inlet is uncontrolled and therefore free to migrate.

This report presents the initial results of a series of laboratory tests made to determine the manner in which beach processes in the vicinity of a tidal inlet differ from those outside the influence of the inlet, and the adjustments which can be expected to occur in a previously unbroken beach following introduction of an inlet.

A total of six tests are reported on; the inlets in the first four tests, however, closed rather quickly due to insufficient tidal prism, and served essentially only as calibrating tests to arrive at a combination of tidal prism, ocean wave characteristics, and inlet characteristics which would result in a migrating inlet that maintained itself. Such an inlet was achieved for tests 5 and 6 -- the difference between these two tests being in the depth of the lagoon, the test 5 lagoon being quite deep so that material carried into the lagoon on the flood tide had no chance to leave the lagoon on the ebb, and the test 6 lagoon being the same depth as the inlet.

The present report was prepared by Thorndike Saville, Jr., Joseph M. Caldwell, and Henry B. Simmons. Messrs. Saville and Caldwell are, respectively, Assistant Chief and Chief of the Research Division of the Beach Erosion Board; Mr. Simmons is Chief, Estuaries Section, Waterways Experiment Station. The experimental program was developed by the Research Division of the Beach Erosion Board and the Tidal Hydraulics Committee of the Corps of Engineers, and was carried out under their general instructions by personnel of the Waterways Experiment Station. Mr. T. J. Kinzer was the project engineer in charge of the actual experimentation, under the general supervision of Mr. Simmons. General Theron D. Weaver was President of the Board at the time the report was prepared; Colonel C. H. Dunn was Director of the Experiment Station during the testing period.

Funds for the study have been provided from the Development Program of the Board, and from the Office, Chief of Engineers, through Civil Works Investigation Projects CW 823 "Effect of Inlets on Adjacent Beaches" (under the cognizance of the Beach Erosion Board) and CW 846 "Effect of Adjacent Shores on Tidal Entrances" (under the cognizance of the Tidal Hydraulics Committee of the Corps of Engineers).

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by
Thorndike Saville, Jr., and Joseph M. Caldwell
Beach Erosion Board
and
Henry B. Simmons
Waterways Experiment Station

Many shore problems are complicated by the existence of a tidal inlet cutting through the shore area and affecting, to some distance on either side of the inlet, the reaction of the shore area to the normally applied littoral forces. The effect of these inlets, and of the general inlet regime, can be large, especially if the inlet is uncontrolled and therefore free to migrate.

A laboratory study has been initiated to determine the manner in which beach processes in the vicinity of a tidal inlet differ from those outside the influence of the inlet, and the adjustments which can be expected to occur in a previously unbroken beach following the introduction of an artificial tidal inlet. No particular area is being modeled, the beach and inlet conditions being general in nature, and considered only as a model of themselves. However, the relationships of wave forces, sand mobility, littoral currents, and tidal action are considered to approximate the relationships for full-scale natural beaches.

The experimental work for this study is being carried out at the Waterways Experiment Station of the Corps of Engineers at Vicksburg, Mississippi, under the general direction of the Research Division of the Beach Erosion Board. Six tests have been completed to date, of which, however, the first four served essentially only to provide a satisfactory adjustment of the model.

The tests have been carried out in an essentially semicircular wave-tide basin of about 50-foot radius, as shown in Figure 1. The tank is 1.5 feet deep and is equipped with a tide-producing mechanism, control, and recorder; and with movable wave machines of the plunger type. A separate pumping system is also available for introducing an additional longshore current. The sand used is a well-sorted (sorting coefficient of 1.16) National Park sand, having a median diameter of 0.23 millimeter, and a skewness of 0.99. It thus has characteristics similar to those of many beach sands. The mechanical analysis is shown in Figure 2.

The tests were run in two parts, one without the inlet in place and one with the inlet cut through. The first part was run until approximate stability had been reached (as indicated by hydrographic stability and constancy of littoral movement); the inlet was then cut through, and the run continued again until approximate stability had again been reached. A lagoon-type inlet was used for all tests to date, the one tested so far having, initially, an inlet length four times the inlet

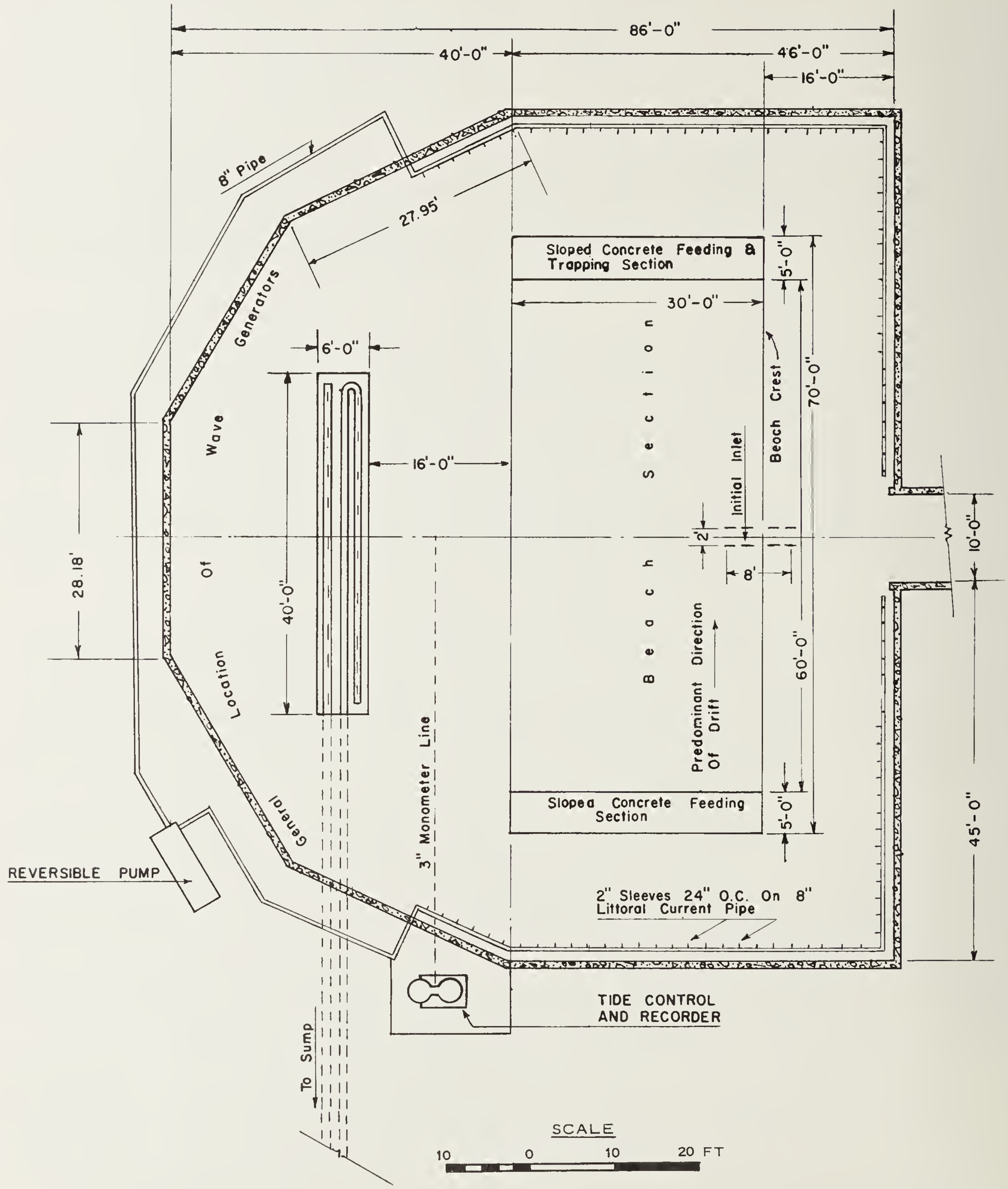


FIGURE 1. TIDAL BASIN

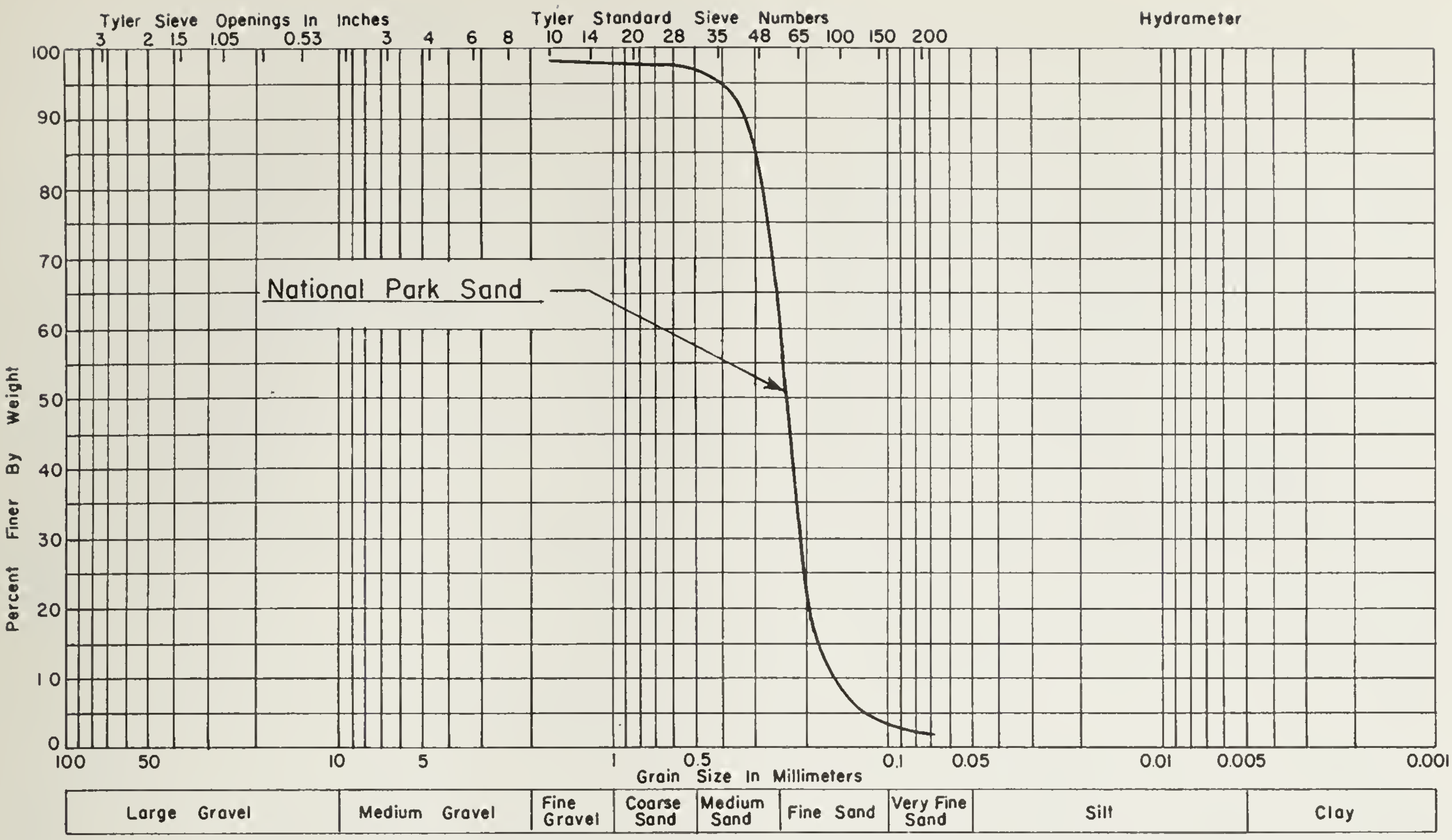


FIGURE 2. MECHANICAL ANALYSIS CURVE

width. (Later tests will involve different inlet width-length ratios.) It was planned that the first tests would involve a relatively unbalanced rate of movement of littoral drift; that is, the direction of movement of the littoral drift would be reversing, but predominantly from one direction. The initial plan was for roughly four units of downcoast drift movement as opposed to one unit of upcoast movement. (Again, a more balanced rate of drift movement, being only slightly dominant from one direction, is planned for later tests.) The tide range and period were, to as near a degree as possible, selected to insure that the inlet maintained itself without undue enlargement or constriction. It appeared that the width of the inlet should not occupy more than 1/50th of the beach, and possibly somewhat less, to insure that the inlet effects would be contained within the test limits, and that a normal flow distribution would exist at the tidal entrance. The controlling inlet depth had to be shallow enough to prevent excessive slumping at the sides and resultant excessive enlargement of the inlet width, and yet deep enough to permit active wave action in the inlet. A depth at mean tide of about twice the incident wave height appeared to be of the right order. A deep-water wave steepness (H_o/L_o) of about 0.025 seemed to be in order, both as representing a wave of intermediate steepness, and, from indications of prior model tests, as being in the general range for producing maximum littoral movement.

After considering the factors listed above in conjunction with the capabilities of the available equipment, a 60-foot length of sand beach was selected as the test section, with 5-foot concrete sloped sections on either side to act as feeding areas, and to reduce end effects on the

wave action incident to the beach section. The beach was initially installed on a 1-on-20 slope with a crest elevation of 0.35 foot. The initial beach profiles, and inlet and lagoon profiles, are shown in Figure 3 for all tests. A water depth of 1.15 feet in the deep, level portion of the tank was used. The inlet itself was initially cut midway in the sand beach section, and had an original depth of 0.2 foot at mean tide level, an original bottom width of 2 feet, an original mean tide level length of 8 feet, and original side slopes of 1 on 5. The lagoon behind the inlet was quite deep for tests 1 through 5, dropping off on a 1-on-5 slope to -1.15 feet behind the inlet. Test 6 involved a shallow lagoon, with an initial rear slope of 1 on 5 to a depth of -0.20 foot. In all cases the total lagoon area was about 2,800 square feet. The tide range was selected as 0.1 foot, with a duration of each tidal cycle (from high to high) of 20 minutes. The deep-water wave height was selected as 0.10 foot, and the period as 0.884 second; a deep-water wave length of 4.0 feet was thus obtained, with a resultant deep-water steepness of 0.025. The wave height in the level portion of the tank (at the generators) where the water depth was 1.15 feet ($d/L_o = 0.29$) was then 0.095 foot. The wave period was kept constant throughout the tests. The wave height, however, varied slightly throughout the tidal cycle as the eccentricity of the plunger arm, and hence the vertical displacement of the plunger remained constant, but the depth of water changed with the tide; this resulted in a constantly varying amount of plunger submersion, and hence a slightly changing wave height and steepness. The values given above were those at mean tide.

The wave machines were mobile, and were oriented in varying directions to produce the desired reversing direction of drift movement and ratio of upcoast and downcoast amounts of movement. A predetermined sequence of wave directions was run through, each direction having a duration of 10 tidal cycles before changing to the next direction. The entire sequence was run (lasting a total of 50 to 60 tidal cycles) and then the sequence was repeated. Hydrographic surveys of the beach and inlet area were made at the completion of each sequence (50 or 60 cycles) and sometimes oftener; in general, the inlet area alone was sounded at the end of each 10 tidal cycles. Current velocities were measured in the inlet gorge over one complete tidal cycle at every 10th tidal cycle, except for tests 1 and 2 when no measurements were made. Current velocities for tests 3 and 4 were measured with a small Price-type current meter capable of measuring velocities down to 0.05 foot per second. These measurements were made in the center of the gorge, at an elevation of -0.07 (mean tide level). For tests 5 and 6, measurements were made at the same location with a float of 0.10-foot submergence. The amount of sand moving on to, and trapped on, the concrete aprons on either side of the test beach was removed and measured at the end of each 5-cycle period from the end of the beach opposite that from which the waves were coming; it was then replaced in the surf zone at the upbeach end. A norm was determined during the (first) stabilization portion of the tests, and any deficiency (in the second portion of the tests) between the sand actually removed and the norm was added in again at the upbeach end.

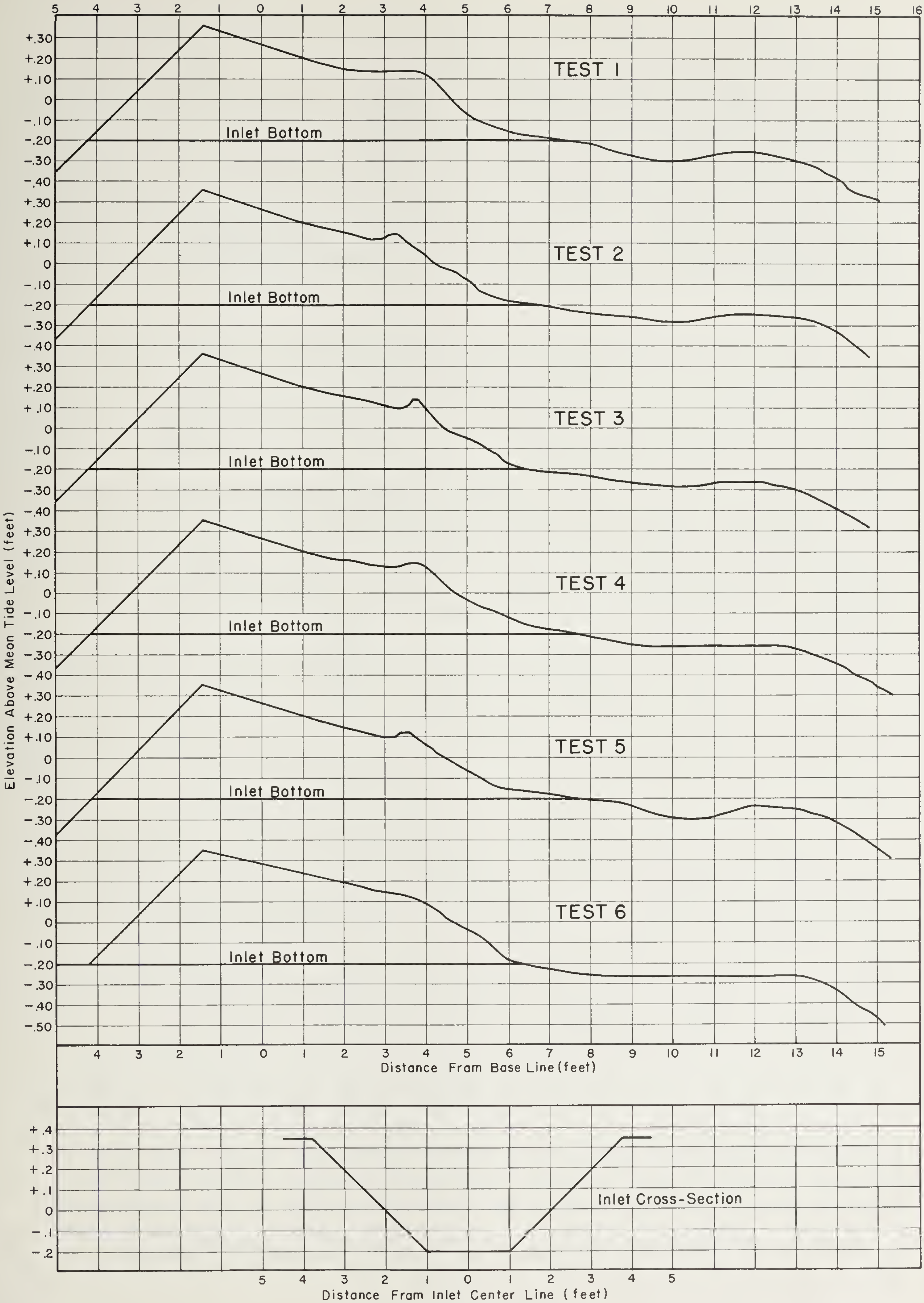


FIGURE 3. BEACH PROFILES ALONG INLET CENTER LINE AT TIME OF CUTTING INLET THROUGH

The individual tests are discussed in the following paragraphs. It is emphasized that the inlet as studied in the test basin was not a small-scale model of any natural inlet; neither was it considered to be a model of a hypothetical prototype. Therefore, the dimensions given in the text of this report are the actual inlet dimensions as tested. These dimensions are summarized in Table 1 for the convenience of the reader. Also, to enable the user to grasp more easily the comparative relation of the various actual test dimensions, these actual dimensions are expanded in accordance with the Froudian relationships by a 1:100 conversion and repeated (in parentheses) in Table 1 at this 1:100 expansion. The interpretation of the data should be at the actual dimensions, and no implication that the test was a model study at a 1:100 scale is intended.

Test 1 had a sequence of wave directions from 15° upbeach, 30° upbeach, 15° downbeach, 15° upbeach, 30° upbeach, and normal to the beach, waves being generated from each direction for 10 tidal cycles (making a total of 60 tidal cycles to complete the sequence). A downbeach littoral current was generated by pumping water from the wave-tide basin at the downbeach end of the beach and returning it at the upbeach end; this current was generated for all wave directions except the one with a downbeach approach. This combination of waves and current resulted in a drift ratio (i.e., ratio of amount of material moved in a downbeach direction to that moved in an upbeach direction) of about 7 to 1. (Actually, the use of the artificially generated (pumped) longshore current was rather unsatisfactory, generating large-scale eddies along the beach which resulted in a very jagged shoreline -- and making determination of shore stability relatively difficult.) Stability of the unbroken beach required operation for 120 tidal cycles (40 hours), or two complete sequences of wave directions. The inlet was then cut through the beach, and the sequence of wave directions resumed. The inlet closed completely during tidal cycle 42 (about 14 hours) after being dredged; this occurred after the change in wave direction from downbeach to upbeach. The inlet had migrated downbeach an appreciable amount during the first 20 tidal cycles; then the seaward end tended to migrate upbeach for the following 10 cycles (waves from the downbeach direction), causing the inlet to become curved and the outer end to be aligned in a direction about 15° upbeach. The following waves from 15° and 30° upbeach transported material directly into the seaward entrance and caused closure of the inlet. No actual hydrographic data were obtained during this test, but the inlet changes are shown schematically in Figure 4 (which follows photograph 13), along with the hydrography after closure at cycle 42.

Test 2 was run with the same sequence of wave directions, but without the artificially induced (pumped) longshore current. It was felt that elimination of the artificial current might reduce the rate of transport and thus increase the life of the inlet, in addition to eliminating the large and undesirable eddies along the beach. The rate of littoral transport was, however, increased somewhat, rather than decreased; the reason appeared to be that elimination of the large-scale eddies also eliminated local countercurrents induced in the surf zone by the eddies, thus permitting a somewhat greater total movement.

TABLE 1

TEST CONDITIONS

NOTE: Dimensions in this table are given first as actual measured values, and then, in parentheses (as an aid to the user in visualizing comparative values) at a 1:100 Froudian expansion. Interpretation and use, however, should be made only at actual dimensions, as the study is not a small-scale study of any hypothetical prototype.

All Tests:

Beach: Ocean slope: 1 on 20

Lagoon slope: 1 on 5

Sand: 0.23-mm. median diameter (actual size)

Ocean tide range: 0.10 feet (10 feet)

Inlet: Bottom width: 2.0 feet (200 feet)

Length at mean tide level: 8.0 feet (800 feet)

Depth at mean tide: 0.20 foot (20 feet)

Low-water depth: 0.15 foot (15 feet)

Length-width ratio: 4 to 1

Side slopes: 1 on 5

Waves: Deep water, mean tide height: 0.10 foot (10 feet)

Deep-water length: 4.0 feet (400 feet)

Period: 0.88 seconds (8.8 seconds)

Steepness: 0.025

	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
Wave direction sequence (10 cycles each):	15°E* 30°E 15°W 15°E 30°E Normal	15°E 30°E 15°W 15°E 30°E Normal	15°E 30°E 15°E 30°E Normal	10°E 15°E 10°E 15°E Normal	15°E 30°E 15°W 15°E 30°E Normal	15°E 30°E 15°W 15°E 30°E Normal
Littoral current:	E (with E waves only)	None	None	None	None	None
Lagoon depth (feet):	1.15 (115)	1.15 (115)	1.15 (115)	1.15 (115)	1.15 (115)	0.20 (20)
Forced lagoon tide:	No	No	No	No	Yes	Yes
Effective lagoon area (sq. ft.):	2800 (1.0 sq. mi.)	2800 (1.0 sq. mi.)	2800 (1.0 sq. mi.)	2800 (1.0 sq. mi.)	4000 (1.4 sq. mi.)	4000 (1.4 sq. mi.)
Tidal prism at start of test (cu. ft.):	192 (1.92×10^8)	192 (1.92×10^8)	192 (1.92×10^8)	192 (1.92×10^8)	273 (2.73×10^8)	273 (2.73×10^8)
Average rate westward drift movement:	0.054 cu ft/cycle (1980) cu yd/cycle	0.068 cu ft/cycle (2530) cu yd/cycle	0.136 cu ft/cycle (5040) cu yd/cycle	0.062 cu ft/cycle (2280) cu yd/cycle	0.054 cu ft/cycle (2020) cu yd/cycle	0.061 cu ft/cycle (2240) cu yd/cycle
Time to reach initial equilibrium (tidal cycles):	120	120	100	100	120	(120)**
Time of closure (tidal cycle):	42	30	31	60	No	No

* E refers to easterly (upbeach direction); i.e., 15°E means waves from 15° upbeach.

** Equilibrium beach modeled to average profile of test 5.

Elimination of the current did, however, result in a much straighter and more even shore, which was felt to be much more representative of the conditions under test. The beach area again stabilized after 120 tidal cycles, the inlet was cut, and the wave sequence resumed. The inlet closed completely during tidal cycle 30 after being dredged, indicating that the rate of littoral transport was too great, or that current velocities through the inlet were too low, to permit the inlet to remain open. The inlet migrated a considerable distance downbeach before closing completely; it appeared that velocities in the inlet were progressively reduced as its length (due to migration) increased, so that material was deposited in the upbeach side of the channel at a greater rate than the current could scour the downbeach side, resulting in a progressively decreasing inlet width, and finally closure. Hydrographic surveys of the inlet area were made after every 5 tidal cycles, and some of these are reproduced in Figure 5.

Test 3 was a repeat of test 2, except that it was planned to omit the waves generated from the downbeach direction (tidal cycles 21-30 in test 2). Elimination of this wave direction reduced the total wave sequence from 60 to 50 tidal cycles, and the stabilization time to 100 tidal cycles. However, the inlet closed completely during tidal cycle 31 after being dredged, indicating that the downbeach wave sequence during test 2 probably was not responsible for the rapid closure of the inlet. Elimination of these waves from test 3 probably had little or no effect on the inlet closure; some effect would have been observed, however, on the stabilized beach contours existing prior to cutting the inlet, and on the ratio of total downbeach to upbeach rate of movement. It would appear that closure of the inlet approximately 30 cycles after being dredged was attributable to the large rate of littoral transport rather than to the sequence of wave directions. Inlet surveys only were obtained at 5-cycle intervals, and some are shown in Figure 6; they may be compared with those for similar times for test 2 shown in Figure 5.

Test 4 operating conditions were the same as for test 3, except that upbeach wave directions of 10° and 15° were substituted for test 3 angles of 15° and 30°. This meant a 50-cycle wave sequence of directions from 10° upbeach, 15° upbeach, 10° upbeach, 15° upbeach, and normal to the beach (all for 10 tidal cycles each), and repeat. It was thought that the reductions in angle would reduce the rate of littoral transport and thus increase the life of the inlet. The inlet closed completely during tidal cycle 60 (20 hours) after being dredged, indicating, as in the previous tests, that either the rate of transport was still too high, or current velocities in the inlet were too low, to permit the inlet to remain open. The life of the inlet for test 4 was twice that for tests 2 and 3; however, the inlet did not migrate appreciably in test 4 as it did in tests 2 and 3. It would therefore appear that the principal cause of closure was low current velocities rather than an excessive rate of littoral movement. The inlet hydrography was determined at 5-cycle intervals, and the entire beach hydrography at cycles 50 and 70. Certain of these are shown in Figures 7A and B.

In view of the experience with tests 1 through 4, it was felt that a forced lagoon tidal flow would be necessary to keep the inlet from closing. This was done by pumping water from the lagoon into another tidal sump during flood tide, and returning the water during ebb flow, while still maintaining the same 0.1-foot tidal difference on the seaward side of the beach. Essentially, this had the effect of increasing the lagoon area, and hence the tidal prism and the current velocities within the inlet. The inlet current, however, was still due only to the (tidal) difference in water-level elevation between the two sides of the beach. The forced tide in the lagoon increased the effective area of the lagoon by a factor of 1.42, from 2,800 to 4,000 square feet. That is, the tidal currents observed with the forced tide were the same as would have occurred with no forced tide had the lagoon area been increased to 4,000 square feet and the inlet cross section remained approximately constant. The forced tide increased the maximum flood and ebb velocities in the inlet to about 1.5 feet per second, as compared to about 1.0 foot per second in the previous tests.

The wave sequence for test 5 was the same as that for test 2: 10 cycles each from a direction 15° upbeach, 30° upbeach, 15° downbeach, 15° upbeach, 30° upbeach, and normal to the beach (making a total of 60 tidal cycles for each sequence), and repeat. As in test 2 stabilization required 120 tidal cycles (40 hours). The test was run for 450 tidal cycles after dredging the inlet without closure. Ranges 5 through 30 and the inlet were sounded at 10-cycle intervals after the inlet had been dredged, and the hydrography for some of these is shown in Figures 8 through 25.

Figure 8 shows the stabilized beach with the inlet as initially cut through. Figure 9 shows the inlet after one complete wave sequence (60 tidal cycles). Although there has apparently been little change in width, depth, or cross-sectional area of the inlet except at the gorge (at about the beach crest), which has narrowed and deepened, the inlet alignment has changed to about a 30- or 35-degree angle with the beach. An inner bar has progressively formed at the lagoon end of the inlet, and a sizeable curved outer bar has formed on the upbeach side of the seaward portion of the inlet.

The progressive downbeach migration was terminated at about cycle 70 when a breakthrough of the bar started to occur on an alignment slightly downbeach from the original alignment. The breakthrough was essentially complete by cycle 80, and completely cut through by cycle 90. Figures 10-12 show the changing hydrography during this breakthrough. Following the breakthrough the inlet again migrated progressively downbeach until about cycle 210, when the migration cycle was again terminated by a breakthrough. Figures 13-17 show the hydrography at 120, 150, 180, 200, and 210 cycles. As may be seen, the outer bar elongated considerably over its position at the first breakthrough (cycle 70), and the inlet channel alignment changed to make about a 45- or 50-degree angle with the beach. The inner bar enlarged progressively throughout the course of the test to this point, and was elongated somewhat in an upbeach direction. Toward

the lagoon side of the beach, the thalweg of the inlet consistently remained on the upbeach side, but a tendency toward formation of a secondary channel along the downbeach side of the inner bar may be noted at cycles 180 and 200 (Figures 15-16). It was apparent that the inner and outer bar cycles were not in phase, and even though two breakthroughs had occurred, a complete inlet cycle was not thought to have been achieved.

At the time of the second breakthrough (cycles 200-210) the deep-water channel on the lagoon side of the gorge was along the upbeach side of the inner bar, so that the breakthrough resulted in a relatively sharp angle in the channel at the gorge (Figures 17-19). Subsequent to the breakthrough, the deep-water channel on the lagoon side of the gorge, and the gorge itself, began a downbeach migration because of the sharp angle at the gorge; during this downbeach migration of the inner channel the deep-water channel seaward of the gorge remained relatively stable, probably because material normally shoaling the upbeach side of this channel and forcing it to migrate was carried inside the inlet and deposited in the abandoned channel on the upbeach side of the inner bar. A large portion of the material scoured from the downbeach side of the inner channel was apparently carried through the gorge and deposited on the downdrift side of the outer channel, thus completely shoaling by cycle 300 the channel abandoned at the time of the breakthrough (Figure 20). As the gorge and inner channel migrated downbeach, a number of minor channels developed through the inner bar (see Figures 21-22, cycles 330-360); continuing migration of the channel, however, redeveloped by cycles 420-450 a single inner channel, about two inlet lengths downbeach from the initial position, which was appreciably deeper than any of the former minor channels. By cycle 450 (Figure 25) essentially the entire channel had gone through a complete migration, and was aligned at only a small angle to the beach -- but had moved downbeach a distance of about two inlet widths. During the course of the inner channel migration, the inner bar was progressively extended, indicating a more or less continuous movement of material through the inlet toward the lagoon.

Throughout the course of test 5 the average amount of sand moving, as measured by entrapment on the concrete slopes to either side of the test area, remained essentially constant. Measured sand amounts, and the deficiency or excess over the norm as determined from the initial beach stabilization portion of the test, are shown in Table 2a. However, the nearshore slope became appreciably flatter, the zero contour moving landward and the -0.30-foot contour moving seaward.

Inasmuch as one complete migration cycle of the inlet as a whole had been obtained by cycle 450, it was felt that further testing of this inlet would not lead to any appreciable additional results, and that continued testing was not justified. It was felt that the next test should be essentially a comparative test, involving a change in only one of the dominant features. The deep lagoon behind the inlet was thought to be unrealistic of many present-day coastal inlets, and it appeared that the next test should therefore involve a change from a deep to a shallow lagoon area. The deep lagoon used in test 5 had essentially

TABLE 2a

SAND MOVEMENT - TEST 5

Cycles (after dredging inlet)	Wave Direction	Sand Removed (cu. ft.) E. End*	Sand Removed (cu. ft.) W. End	Excess (cu. ft.)	Deficiency (cu. ft.)	Sand Added (cu. ft.) E. End	Sand Added (cu. ft.) W. End
0-5	15°E		0.27		0.15**	0.27	
6-10	15°E		0.46	0.04		0.46	
11-15	30°E		1.00	0.28		1.00	
16-20	30°E		1.12	0.40			1.12
21-25	15°W	0.13			0.30**		0.13
26-30	15°W	0.11			0.32**	0.11	
31-35	15°E		0.54	0.12		0.54	
36-40	15°E		0.62	0.20		0.62	
41-45	30°E		0.82	0.10		0.82	
46-50	30°E		0.73	0.01		0.36	0.36
51-55	Normal	0.08	0.20		0.02**	0.08	0.20
56-60	Normal	0.04	0.18		0.08**	0.22	
61-65	15°E		0.43	0.01		0.43	
66-70	15°E		0.36		0.06	0.42	
71-75	30°E		0.52		0.20	0.72	
76-80	30°E		0.39		0.33		0.72
81-85	15°W	0.21			0.22		0.43
86-90	15°W	0.22			0.21	0.43	
91-95	15°E		0.21		0.21	0.21	
96-100	15°E		0.15		0.06	0.21	
101-105	30°E		0.27		0.09	0.36	
106-110	30°E		0.28		0.08	0.18	0.18
111-115	Normal	0.23	0.14	0.12		0.23	0.14
116-120	Normal	0.20	0.13	0.18		0.33	
121-125	15°E		0.13		0.08	0.08	
126-130	15°E		0.14		0.07	0.07	
131-135	30°E		0.27		0.09	0.36	
136-140	30°E		0.34		0.03		0.36
141-145	15°W	0.31		0.10			0.31
146-150	15°W	0.37		0.16		0.37	
151-155	15°E		0.09		0.12	0.21	
156-160	15°E		0.10		0.11	0.21	
161-165	30°E		0.52	0.16		0.52	
166-170	30°E		0.62	0.26		0.31	0.31
171-175	Normal	0.06	0.12	0.03		0.06	0.12
176-180	Normal	0.05	0.08		0.02		0.15
181-185	15°E		0.17		0.04	0.21	
186-190	15°E		0.22	0.01		0.22	
191-195	30°E		0.58	0.22		0.58	
196-200	30°E		0.60	0.24			0.60
201-205	15°W	0.36		0.15			0.36
206-210	15°W	0.35		0.14		0.35	
211-215	15°E		0.27	0.06		0.27	
216-220	15°E		0.31	0.10		0.31	
221-225	30°E		0.32		0.04	0.36	

Cycles (after dredging inlet)	Wave Direction	Sand Removed (cu. ft.) E. End*	Sand Removed (cu. ft.) W. End	Excess (cu. ft.)	Deficiency (cu. ft.)	Sand Added (cu. ft.) E. End	Sand Added (cu. ft.) W. End
226-230	30°E		0.24		0.12	0.18	0.18
231-235	Normal	0.11	0.17	0.13		0.11	0.17
236-240	Normal	0.15	0.11	0.11		0.26	
241-245	15°E		0.10		0.11	0.21	
246-250	15°E		0.09		0.12	0.21	
251-255	30°E		0.24		0.12	0.36	
256-260	30°E		0.24		0.12		0.36
261-265	15°W	0.14			0.07		0.21
266-270	15°W	0.23		0.02		0.23	
271-275	15°E		0.28		0.07	0.28	
276-280	15°E		0.30		0.09	0.30	
281-285	30°E		0.68	0.32		0.68	
286-290	30°E		0.64	0.28		0.32	0.32
291-295	Normal	0.05	0.31	0.21		0.05	0.31
296-300	Normal	0.05	0.20	0.10		0.25	
301-305	15°E		0.29	0.08		0.29	
306-310	15°E		0.21			0.21	
311-315	30°E		0.41	0:05		0.41	
316-320	30°E		0.60	0.24			0.60
321-325	15°W	0.15			0.06		0.21
326-330	15°W	0.17			0.04	0.21	
331-335	15°E		0.26	0.05		0.26	
336-340	15°E		0.25	0.04		0.25	
341-345	30°E		0.47	0.11		0.47	
346-350	30°E		0.61	0.25		0.13	0.13
351-355	Normal	0.06	0.15	0.06		0.06	0.15
356-360	Normal	0.11	0.13	0.09		0.24	
361-365	15°W	0.17			0.04		0.21
366-370	15°W	0.18			0.03	0.21	
371-375	15°E		0.18		0.03	0.21	
376-380	15°E		0.25	0.04		0.24	
381-385	30°E		0.33	0.04		0.33	
386-390	30°E		0.59	0.23			0.59
391-395	15°W	0.24		0.03		0.24	
396-400	15°E		0.19		0.02	0.21	
401-405	30°E		0.48	0.12		0.48	
406-410	30°E		0.48	0.12		0.24	0.24
411-415	Normal	0.08	0.13	0.06		0.08	0.13
416-420	Normal	0.10	0.05			0.15	
421-425	15°E		0.16		0.05	0.21	
426-430	15°E		0.21			0.21	
431-435	30°E		0.42	0.06		0.42	
436-440	30°E		0.39	0.03			0.39
441-445	15°W	0.17			0.04		0.21
446-450	15°W	0.26		0.05		0.26	
TOTAL 0-450		5.14	24.54	6.01	4.06	21.95	9.90

Excess added at E. end 2.16 cu. ft.
Excess added at W. end 1.03 cu. ft.

* E refers to upbeach end.
** Not added.

TABLE 2b

SAND MOVEMENT - TEST 6

Cycles (after dredging inlet)	Wave Direction	Sand Removed (cu. ft.) E. End*	Sand Removed (cu. ft.) W. End	Excess (cu. ft.)	Deficiency (cu. ft.)	Sand Added (cu. ft.) E. End	Sand Added (cu. ft.) W. End
0-5	15°E		0.20	0.01		0.21	
6-10	15°E		0.33	0.12		0.33	
11-15	30°E		0.31		0.05	0.36	
16-20	30°E		0.44	0.08			0.44
21-25	15°W	0.25		0.04			0.25
26-30	15°W	0.26		0.05		0.26	
31-35	15°E		0.31	0.10		0.31	
36-40	15°E		0.13		0.08	0.21	
41-45	30°E		0.25		0.11	0.36	
46-50	30°E		0.43	0.07		0.21	0.21
51-55	Normal	0.09	0.19	0.13		0.09	0.19
56-60	Normal	0.11	0.13	0.09		0.24	
61-65	15°E		0.13		0.08	0.21	
66-70	15°E		0.14		0.07	0.21	
71-75	30°E		0.53	0.17		0.53	
76-80	30°E		0.88	0.52			0.88
81-85	15°W	0.19			0.02		0.21
86-90	15°W	0.15			0.16	0.21	
91-95	15°E		0.21			0.21	
96-100	15°E		0.34	0.13		0.34	
101-105	30°E		0.72	0.36		0.72	
106-110	30°E		1.05	0.69		0.53	0.53
111-115	Normal	0.04	0.15	0.04		0.04	0.15
116-120	Normal	0.03	0.10		0.02	0.15	
121-125	15°E		0.12		0.09	0.21	
126-130	15°E		0.43	0.22		0.43	
131-135	30°E		0.18		0.18	0.36	
136-140	30°E		0.70	0.34			0.70
141-145	15°W	0.07			0.14		0.21
146-150	15°W	0.04			0.17	0.21	

Cycles (after dredging inlet)	Wave Direction	Sand Removed (cu. ft.) E. End*	Sand Removed (cu. ft.) W. End	Excess (cu. ft.)	Deficiency (cu. ft.)	Sand Added (cu. ft.) E. End	Sand Added (cu. ft.) W. End
151-155	15°E		0.11		0.10	0.21	
156-160	15°E		0.49	0.28		0.49	
161-165	30°E		0.50	0.14		0.50	
166-170	30°E		0.74	0.38		0.37	0.37
171-175	Normal	0.05	0.14	0.04		0.05	0.14
176-180	Normal	0.05	0.13	0.03		0.18	
181-185	15°E		0.25	0.04		0.04	
186-190	15°E		0.44	0.23		0.44	
191-195	30°E		0.42	0.06		0.42	
196-200	30°E		0.68	0.32			0.68
201-205	15°W	0.07			0.14		0.21
206-210	15°W	0.02			0.19	0.21	
211-215	15°E		0.26	0.05		0.26	
216-220	15°E		0.37	0.16		0.37	
221-225	30°E		0.60	0.24		0.60	
226-230	30°E		0.76	0.40		0.20	0.20
231-235	Normal		0.20	0.05			0.20
236-240	Normal	0.05	0.17	0.07		0.22	
241-245	15°E		0.25	0.04		0.25	
246-250	15°E		0.48	0.27		0.48	
251-255	30°E		0.46	0.10		0.46	
256-260	30°E		0.58	0.22			0.58
261-265	15°W	0.04			0.17		0.21
266-270	15°W	0.09			0.12	0.21	
271-275	15°E		0.18		0.03	0.21	
276-280	15°E		0.30	0.09		0.30	
281-285	30°E		0.43	0.07		0.43	
286-290	30°E		0.57	0.21		0.28	0.28
291-295	Normal	0.06	0.08		0.01	0.06	0.08
296-300	Normal	0.12	0.19	0.16		0.31	
TOTAL 0-300		1.78	18.18	6.81	1.93	14.49	6.72

Excess added at E. end 1.46 cu. ft.
Excess added at W. end 0.47 cu. ft.

* E refers to upbeach end.

acted as a sediment sump, so that when material was moved through the inlet into the lagoon on the flood flow, it dropped to such depths in the lagoon that it could not be removed on the ebb flow and was no longer available for transport. With a shallow lagoon, material moved in on the flood flow would still be available for removal on the ebb flow. It was felt this would allow the delta formation inside the inlet to build up more nearly in accordance with natural processes.

Consequently, it was decided to repeat test 5 with the lagoon molded to a constant depth of 0.2 foot at mean tide level (i.e., the same depth as the inlet). Rather than initially remolding to a smooth slope and running the 120 tidal cycles to obtain a stabilized beach, an average profile was determined from the stabilized beach of test 5, and the beach for test 6 was then molded to this profile. Forty cycles of waves normal to the beach were then generated, and the inlet was then dredged. Figure 26 shows the stabilized beach with the inlet as initially cut through. The wave and tide characteristics were identical with those of test 5, the pumping of water from the lagoon again effectively increasing the lagoon area to 4,000 square feet, and increasing the tidal prism and resultant currents to values identical with those of test 5 -- and sufficient to prevent deterioration and closure of the inlet.

The hydrography of the inlet area was sounded after every 10 tidal cycles, and the entire beach area after every 60 cycles. The latter are reproduced as Figures 27-31. From a comparison with those obtained in test 5 it may be seen that the initial downbeach migration of the inlet was somewhat slower in test 6 than in test 5. Current velocities in the inlet at cycle 60 were about the same, but were appreciably lower in test 6 at cycle 120 (Table 3), due to the much wider gorge developed in test 6. The height of the beach bar built out as the inlet migrated downbeach remained sufficient throughout the test to prevent overtopping by wave action, and any resulting breakthrough such as occurred in test 5. Hence the apparent rate of migration after about cycle 100 was much greater in test 6. The inner channel and gorge remained on the updrift side of the inlet throughout, and did not migrate downbeach as in test 5. This resulted in (Figure 31) the development of a long barrier beach, the actual inlet mouth having migrated about three inlet widths downbeach while the lagoon side of the inlet remained at essentially the same spot. It appeared that no natural breakthrough would occur under these test conditions, and it was decided to simulate a storm breakthrough by raising the tidal level as though from a storm to permit a breakthrough to occur. Testing would then be resumed with normal prestorm tide test conditions. The range of tide would remain normal (0.1 foot), but mean tide level would be raised in equal increments from 0.0 mtl to +0.05 mtl during three tidal cycles, followed by three tidal cycles with mean tide level at +0.05. If a definite indication of a breakthrough of the inlet was noted during these six tidal cycles, mean tide level would be lowered in equal increments during the next three tidal cycles to a normal elevation of 0.0; however, if no definite indication of a breakthrough was noted, mean tide level would be raised

TABLE 3

CURRENT VELOCITIES IN INLET, TESTS 5 AND 6

Velocities in feet per second

Hour	Cycle 60				Cycle 120				Cycle 180				Cycle 240				Cycle 300			
	Test 5		Test 6		Test 5		Test 6		Test 5		Test 6		Test 5		Test 6		Test 5		Test 6	
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.
0.0	F	0.62	F	0.43	F	1.00	F	0.20	F	0.67	S	0.00	F	0.59	E	0.20	F	0.56	E	0.45
0.5	F	0.87	F	1.00	F	1.11	F	0.74	F	0.71	F	0.47	F	0.80	F	0.47	F	0.69	S	0.00
1.0	F	1.00	F	1.33	F	1.33	F	0.87	F	0.91	F	0.87	F	0.87	F	0.71	F	0.91	F	0.50
1.5	F	1.11	F	1.56	F	1.25	F	1.18	F	1.11	F	1.00	F	0.95	F	1.00	F	1.00	F	0.71
2.0	F	1.25	F	1.43	F	1.66	F	1.33	F	1.11	F	1.25	F	1.00	F	1.00	F	0.91	F	0.83
2.5	F	1.25	F	1.56	F	1.43	F	1.25	F	1.00	F	1.25	F	1.05	F	1.11	F	1.11	F	1.11
3.0 (H.W.)	F	1.18	F	1.56	F	1.43	F	1.43	F	1.00	F	1.25	F	1.11	F	1.25	F	1.11	F	1.11
3.5	F	1.04	F	1.43	F	1.25	F	1.43	F	1.00	F	1.00	F	1.00	F	1.33	F	0.91	F	1.11
4.0	F	0.90	F	1.05	F	1.00	F	1.11	F	0.83	F	1.00	F	0.91	F	1.33	F	0.83	F	1.00
4.5	F	0.83	F	1.00	F	0.87	F	0.71	F	0.77	F	1.00	F	0.67	F	1.11	F	0.59	F	0.83
5.0	F	0.52	F	0.77	F	0.45	F	0.67	F	0.56	F	0.77	F	0.37	F	1.00	F	0.45	F	0.77
5.5	S	0.00	S	0.00	S	0.00	F	0.36	S	0.00	F	0.59	S	0.00	F	0.55	S	0.00	F	0.59
6.0	E	0.58	E	0.36	E	0.69	S	0.00	E	0.48	F	0.20	E	0.71	F	0.34	E	0.50	F	0.48
6.5	E	0.83	E	0.80	E	0.91	E	0.67	E	0.67	E	0.34	E	0.71	S	0.00	E	0.71	F	0.20
7.0	E	1.25	E	1.18	E	1.11	E	0.71	E	0.67	E	0.40	E	0.83	E	0.34	E	0.83	E	0.23
7.5	E	1.43	E	1.25	E	1.25	E	1.00	E	0.83	E	0.60	E	1.00	E	0.47	E	1.00	E	0.50
8.0	E	1.56	E	1.43	E	1.43	E	1.11	E	0.91	E	0.67	E	1.11	E	0.53	E	1.11	E	0.59
8.5	E	1.66	E	1.56	E	1.43	E	1.25	E	1.11	E	0.80	E	1.11	E	0.77	E	1.11	E	0.67
9.0 (L.W.)	E	1.56	E	1.33	E	1.66	E	1.11	E	1.05	E	0.87	E	1.11	E	0.83	E	1.25	E	0.77
9.5	E	1.56	E	1.56	E	1.66	E	1.25	E	1.11	E	1.00	E	1.11	E	0.91	E	1.11	E	0.77
10.0	E	1.25	E	1.56	E	1.43	E	1.18	E	0.87	E	1.00	E	1.18	E	0.91	E	1.11	E	0.77
10.5	E	1.25	E	1.43	E	1.25	E	1.11	E	0.77	E	1.11	E	1.00	E	1.00	E	1.00	E	0.77
11.0	E	1.04	E	1.33	E	0.91	E	1.00	E	0.45	E	1.00	E	0.77	E	0.83	E	0.77	E	0.71
11.5	E	0.77	E	1.11	E	0.62	E	0.87	E	0.45	E	0.71	E	0.56	E	0.71	E	0.50	E	0.67
12.0	E	0.20	E	0.43	F	0.38	E	0.50	F	0.29	E	0.38	S	0.00	E	0.40	F	0.24	E	0.59

slightly above +0.05 for one or two tidal cycles before being reduced in increments to a normal elevation of 0.0. The reason for basing maximum mean tide level on indications of an inlet breakthrough (rather than some predetermined value) was that the elevation of the offshore bar existing at the end of the normal portion of test 6 was about +0.10 mtl, and the occurrence of a breakthrough appeared questionable unless the mean tide level was raised sufficiently to permit flow over the bar crest during some portion of the tidal cycle.

Wave heights and periods would remain as before, and a wave direction of 15° upbeach would be used throughout the storm-tide test.

The elevations of mean tide level, high tide, and low tide produced during the actual storm-tide test are presented in Table 4. Cycle 1 was a normal cycle, in that the characteristics of the tide were identical with those of the previous 300 cycles of the test. During cycles 302-304 mean tide level was raised in increments of about 0.017 foot to an elevation of +0.05 mtl; this was accomplished by raising the successive high waters by an increment of 0.017 foot per cycle (i.e., using a flood range of 0.117 foot), but keeping the ebb range of tide at 0.10 foot. Cycles 305 and 306 were run with mean tide level at this elevation (+0.05). By the end of cycle 306 it was not certain that a breakthrough of the inlet would occur, although there were indications to this effect as will be discussed later; hence the high tide level was raised an additional 0.017 foot to a high water of +0.117 by adding 0.017 foot to the flood range of the tide. It was quickly apparent that a breakthrough would occur, and it was decided to start reducing the mean tide level immediately without further operation at this level or further increases in tide level. Mean tide level therefore was lowered in three increments of about 0.022 foot during cycles 308-310, so that mean tide level was at a normal elevation of 0.0 by the end of cycle 310. This was done by increasing the ebb range for this cycle (307) to 0.117 foot to bring low water for this cycle back to zero; the flood range for cycle 308 was reduced to approximately 0.10 foot and, to reduce the tide level, further reduced to about 0.07 foot for cycles 309 and 310. The ebb range was kept at approximately 0.1 foot for cycles 308-310. This brought the mean tide level back to a normal elevation of 0.0 at the end of cycle 310.

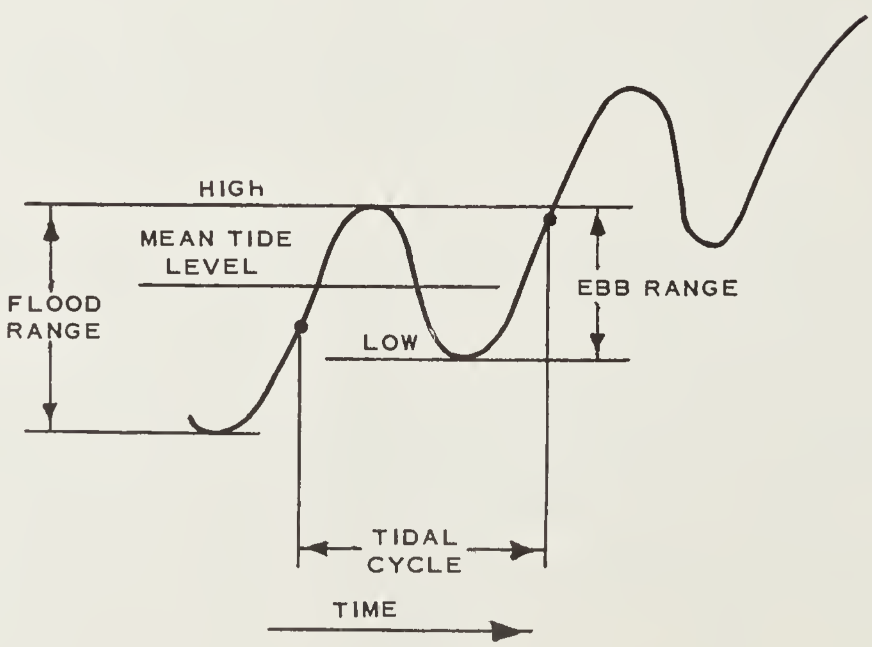
The crest elevation of the outer bar at the end of the normal 300 cycles of test 6 (above +0.10 mtl) was such that wave wash did not pass over the bar even at high tide. A similar situation existed during cycle 301, since the characteristics of the tide were normal. Some wave wash crossed the bar during high tide of cycle 302, and an appreciable amount during high tide of cycle 303. Beginning with low tide of cycle 304, photographs of the bar were made at each low tide and high tide for the remainder of the test, and attempts were made to locate as accurately as possible the 0.0 mtl contours on the low-tide photographs and the +0.10 mtl contours on the high-tide photographs. The location of these contours was subject to some error, since they were determined visually, there being no time to locate them by accurate means; however, it is believed that they were located with sufficient accuracy to depict development of the inlet breakthrough.

TABLE 4

DATA FOR STORM TIDES

Tidal Cycle (after dredging)	Elevation of High Water (ft.)	Elevation of Low Water (ft.)	Elevation of Mean Tide Level* (ft.)	Ebb Range (ft.)	Flood Range** (ft.)
301	+0.05	-0.05	0.00	0.10	0.10
302	+0.067	-0.033	+0.017	0.10	0.117
303	+0.084	-0.016	+0.034	0.10	0.117
304	+0.10	0.00	+0.05	0.10	0.117
305	+0.10	0.00	+0.05	0.10	0.10
306	+0.10	0.00	+0.05	0.10	0.10
307	+0.117	0.00	+0.0585	0.117	0.117
308	+0.093	0.00	+0.0465	0.093	0.093
309	+0.071	-0.025	+0.023	0.096	0.071
310	+0.05	-0.050	0.00	0.10	0.075

* Mid-elevation of ebb tide (see figure below).
** Flood range is from low tide on previous cycle.



Examination of Photograph 1 (low tide, cycle 304) shows that the width of the outer bar was not decreased appreciably during the first three cycles of the test, but wave wash across the bar had reduced the crest elevation over a relatively wide section in the vicinity of sounding range 20. There was no flow across the bar crest at the time of Photograph 1. Photograph 2 (high tide, cycle 304) shows a fairly good flow, consisting mainly of wave wash, across the bar in this same locality. This photograph also shows that material washed from the bar crest by the waves was deposited as a bar in the inlet opposite the low section of the outer bar. Photograph 3 (low tide, cycle 305) shows that the width and depth of the low section of the bar had increased. The elevation of the low section at this time was approximately 0.0 mtl, which was also the elevation of low tide, so there was little, if any, flow across the low section at the time of Photograph 3. Photograph 4 (high tide, cycle 305) shows that flow across the low section of the bar had increased appreciably, as compared to Photograph 2, and that the width of the low section was increasing by erosion of the downbeach side. Photograph 5 (low tide, cycle 306) shows that the elevation of the low section of the bar had decreased to such extent that a fairly good flow across the bar existed at low tide. Photograph 6 (high tide, cycle 306) shows that the depth and width of the low section across the bar was still increasing; also, that the bar in the inlet channel resulting from removal of material from the outer bar was still increasing in size. Photograph 7 (low tide, cycle 307) shows that the depth and width of the low section across the outer bar had increased to such extent as to permit an appreciable flow across the bar at low tide. This photograph shows a fairly definite channel across the bar for the first time during the storm-tide test, but the bottom elevation of this channel was still above the normal elevation of mean tide level.

At this stage of the test, it was necessary to reach a decision as to whether to run one more cycle with the mean tide level at +0.05 foot and then decrease the mean tide level in progressive increments to 0.0, or whether to raise the mean tide level still further to insure a breakthrough of the outer bar. It seemed probable that a breakthrough would occur during the series of tides in which the mean tide level was being lowered, since ebb flow in the inlet would predominate over flood flow during such period; however, it was decided to raise the mean tide level by an additional small amount to insure that a definite breakthrough would occur. Consequently, a high tide of +0.117 mtl was produced for cycle 307.

Photograph 8 (high tide, cycle 307) shows the extremely strong flow across the bar which occurred during the high tide (+0.117 mtl) of cycle 307. A very large amount of material was washed from the outer bar into the inlet channel during this cycle, and the depth of the channel across the bar, as noted on Photograph 7, increased to such extent that it was decided to start reducing mean tide level without further operation at this elevation or further increases in mean tide level. Photograph 9 (low tide, cycle 308) shows a sufficiently strong flow in the channel across the outer bar to dispel any remaining doubt as to the occurrence

of a breakthrough. At this stage of the test, the bottom elevation of the channel across the bar was estimated to be appreciably below the normal elevation of mean tide level. Photograph 10 (high tide, cycle 308) shows that the width of the low section of the outer bar was still increasing, and that the size of the bar formed in the inlet channel by material washed from the outer bar was now being decreased by strong ebb velocities in the inlet. Photograph 11 (low tide, cycle 309) shows a very definite channel over the outer bar; comparison of Photographs 9 and 11 shows that the new channel across the bar migrated downbeach appreciably between cycles 308 and 309. This rapid rate of channel migration is believed to be attributable to the large amount of littoral drift produced during the storm conditions, coupled with the effects of the bar projecting into the inlet channel in the direction of the ebb currents in the inlet. Photograph 12 (high tide, cycle 309) shows a strong flood flow in the new channel across the bar, and also that the eroded portion of the bar upbeach from the new channel was increasing in elevation. The size of the bar formed in the inlet channel by material eroded from the outer bar had been appreciably reduced at this stage of the test. Photograph 13 (low tide, cycle 310) shows the well-developed new channel across the outer bar; comparison of Photographs 11 and 13 shows the relatively rapid rate of downbeach migration of the inlet between cycles 309 and 310.

Figure 32 shows the condition of the inlet and adjacent areas at the end of tidal cycle 310, or at the termination of the storm-tide test. The new channel across the outer bar was located on about sounding range 21, and had a minimum depth of slightly less than -0.10 mtl. A portion of the old channel may be seen downbeach from the new one, but the detached offshore bar, created by the breakthrough, was moving steadily toward the shore during the latter stages of the test and would soon have obliterated all traces of the old channel.

As described in connection with the sequence photographs, the first definite indication of the new channel was in the vicinity of sounding range 20. The channel showed little, if any, tendency to migrate downbeach until it was fairly well developed, about cycle 307, following which it migrated downbeach at a rapid rate to the vecinity of sounding range 21 by the end of cycle 310. All of this migration occurred within that portion of the original outer bar which had been flattened appreciably by the storm waves, and the rate of migration would likely have decreased as the new channel approached the detached portion of the outer bar.

Figure 32 also shows a tendency toward further straightening of the inlet channel by the abandonment of the old channel on the upbeach side and the scouring of a new inner channel on the downbeach side. The first indication of the change in location of the inner channel occurred soon after the waves began removing appreciable quantities of material from the outer bar crest and depositing it on the inner face in the form of a bar projecting into the inlet. This bar formation had the effect of diverting both flood and ebb currents in the inlet from the upbeach to

the downbeach side, and scouring of the new inner channel developed quickly. While this new channel had not developed completely at the end of cycle 310, there appears little doubt that it would have developed further had the test been continued.

The results of the storm-tide test indicate that such tides are a necessary force in causing an inlet to break through the type of outer bar formed during the normal 300 cycles of test 6. It is believed that a breakthrough of the inlet channel would have occurred, regardless of the direction of approach of the storm waves; however, there were indications that the exact location of the breakthrough was affected appreciably by the wave direction. Had the wave direction been 30° upbeach instead of 15°, it appears likely that the breakthrough would have occurred farther downbeach; had the wave direction been normal to the beach or from the west quadrant, it seems likely that the breakthrough would have occurred farther upbeach.

Photograph 1. Approximate location of 0 contour, low tide, cycle 304

Photograph 2. Approximate location of +10 contour, high tide, cycle 304

Photograph 3. Approximate location, 0 contour, low tide, cycle 305

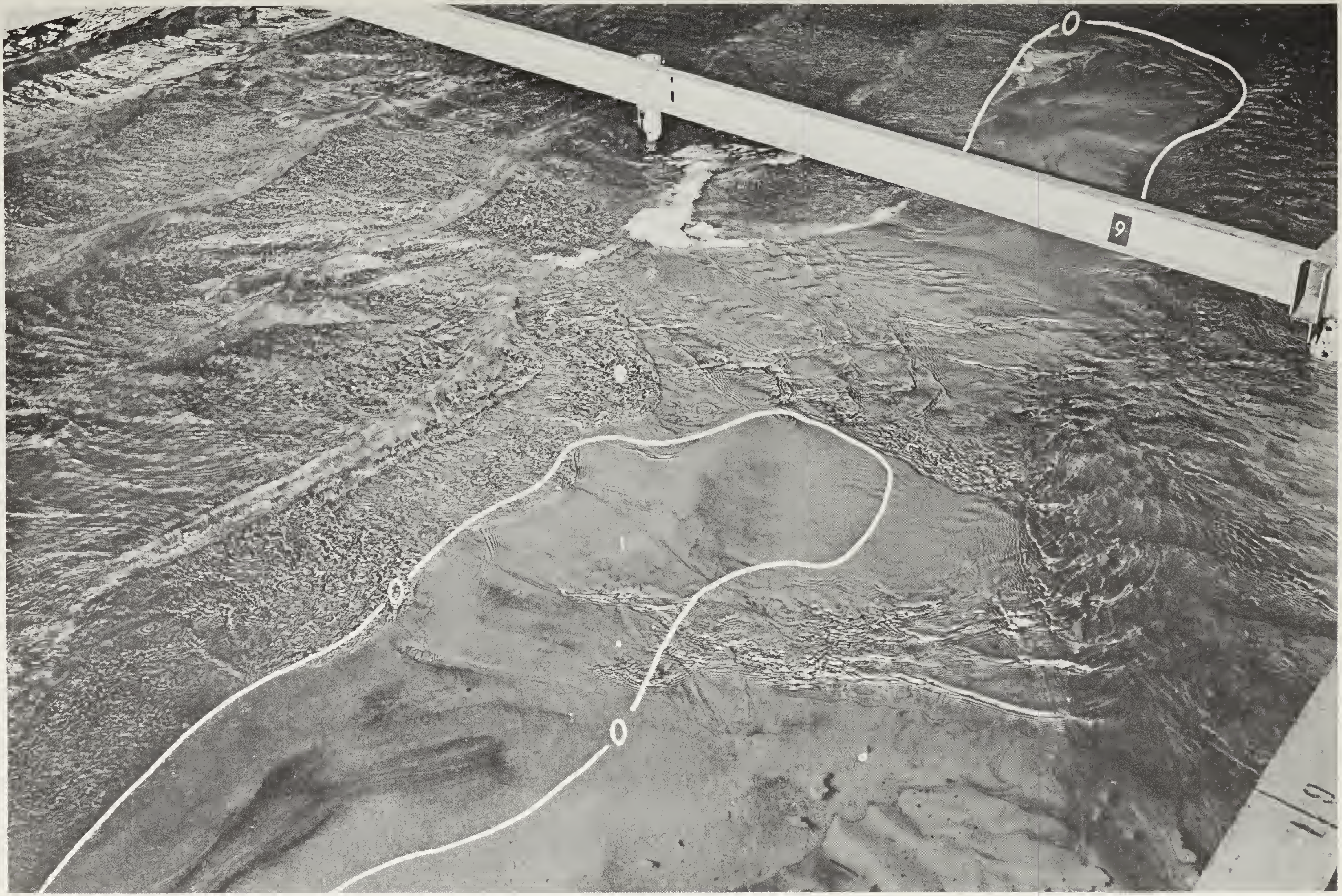
Photograph 4. Approximate location of +10 contour, high tide, cycle 305

Photograph 5. Approximate location, 0 contour, low tide, cycle 306

Photograph 6. Approximate location, +10 contour, high tide, cycle 306

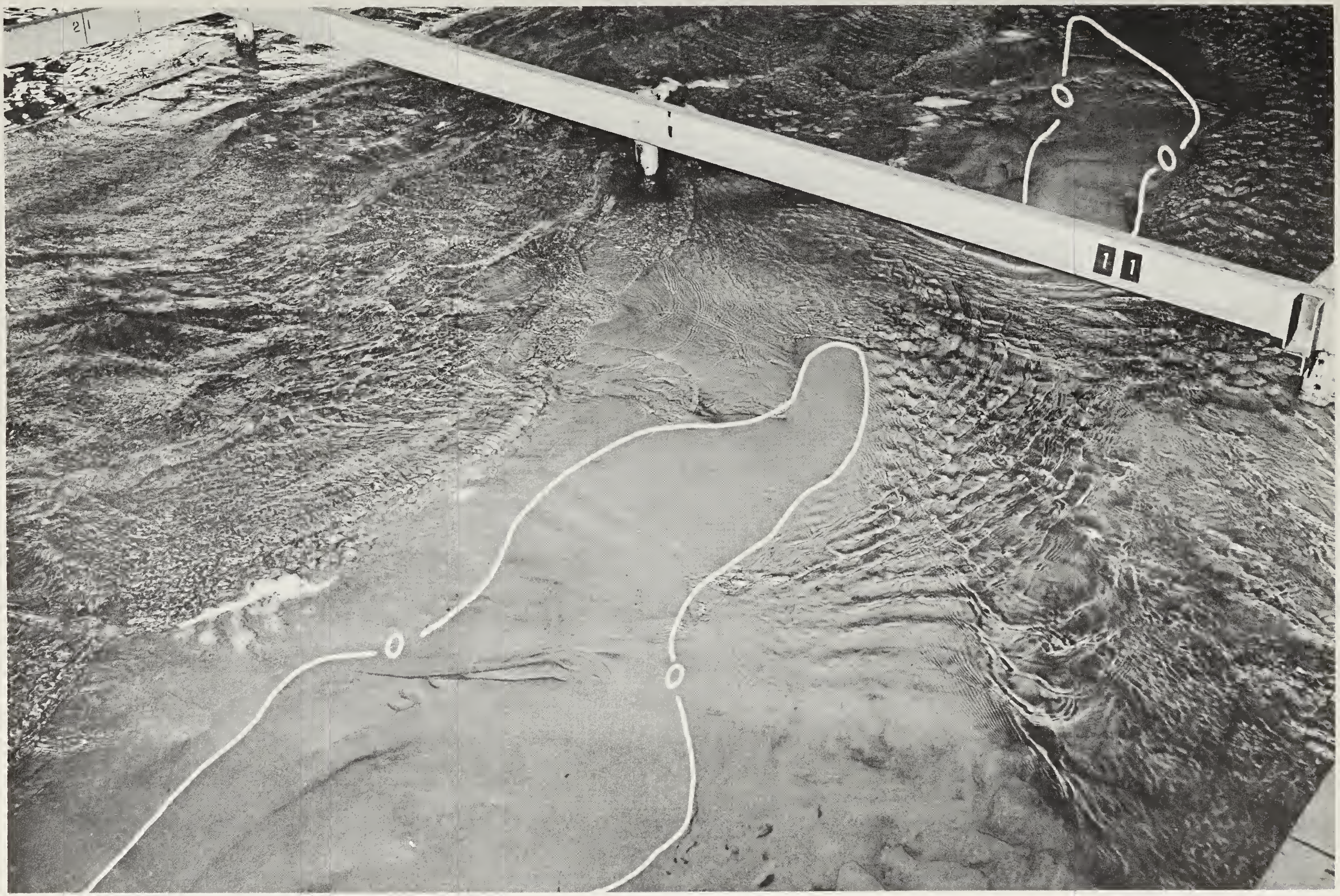
Photograph 7. Approximate location of 0 contour, low tide, cycle 307

Photograph 8. Approximate location of +10 contour, high tide, cycle 307



Photograph 9. Approximate location of 0 contour, low tide, cycle 308

Photograph 10. Approximate location of +10 contour, high tide, cycle 308



Photograph 11. Approximate location of 0 contour, low tide, cycle 309

Photograph 12. Approximate location of +10 contour, high tide, cycle 309

Photograph 13. Approximate location of 0 contour, low tide, cycle 310

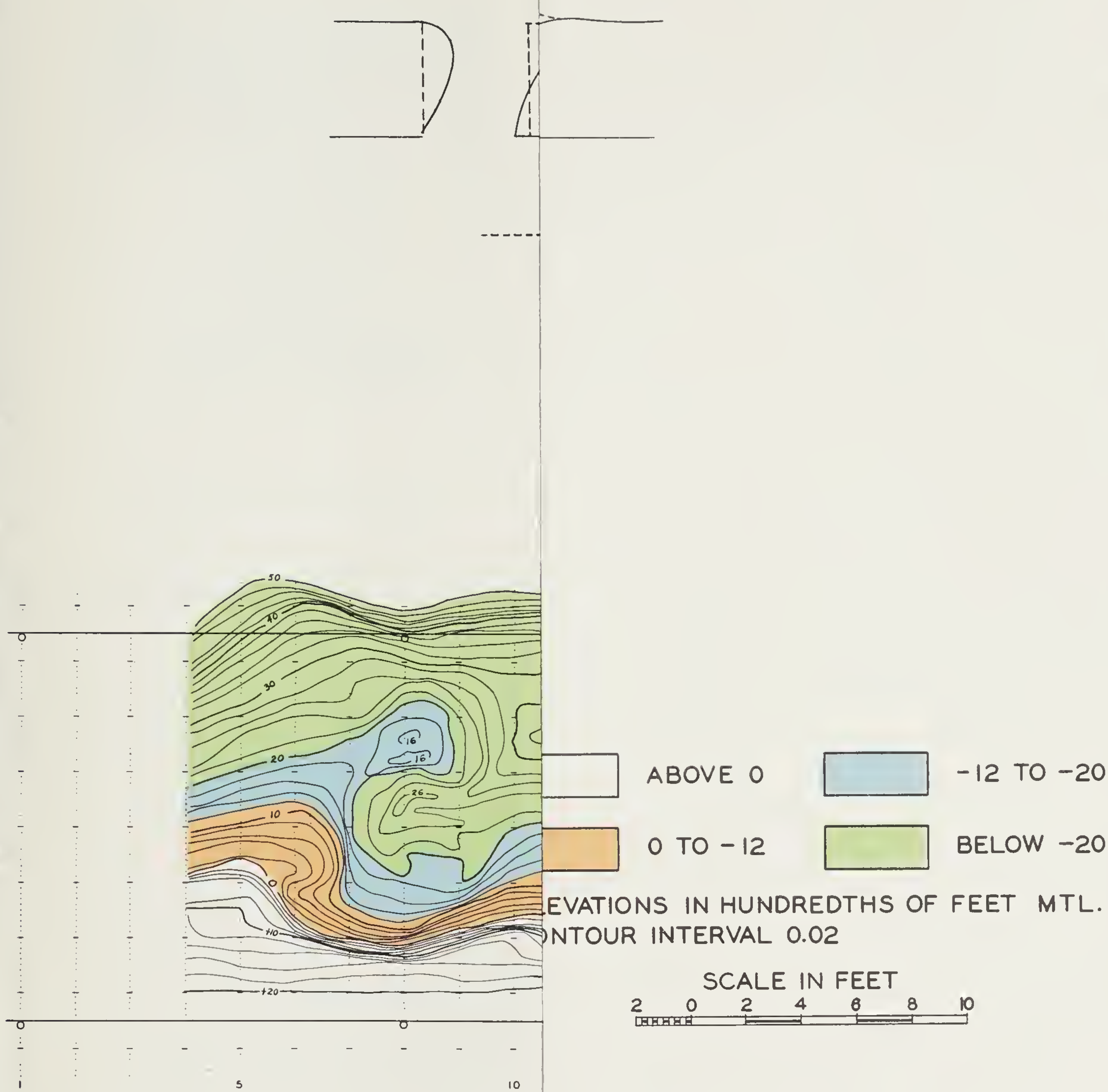
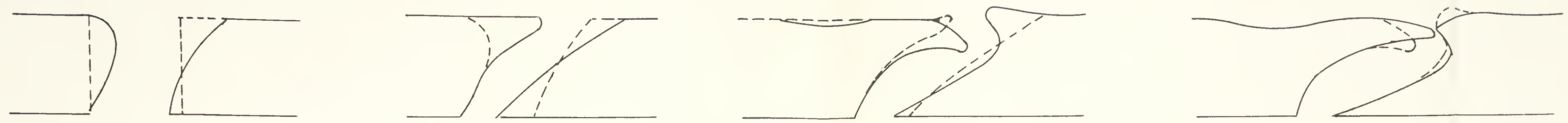


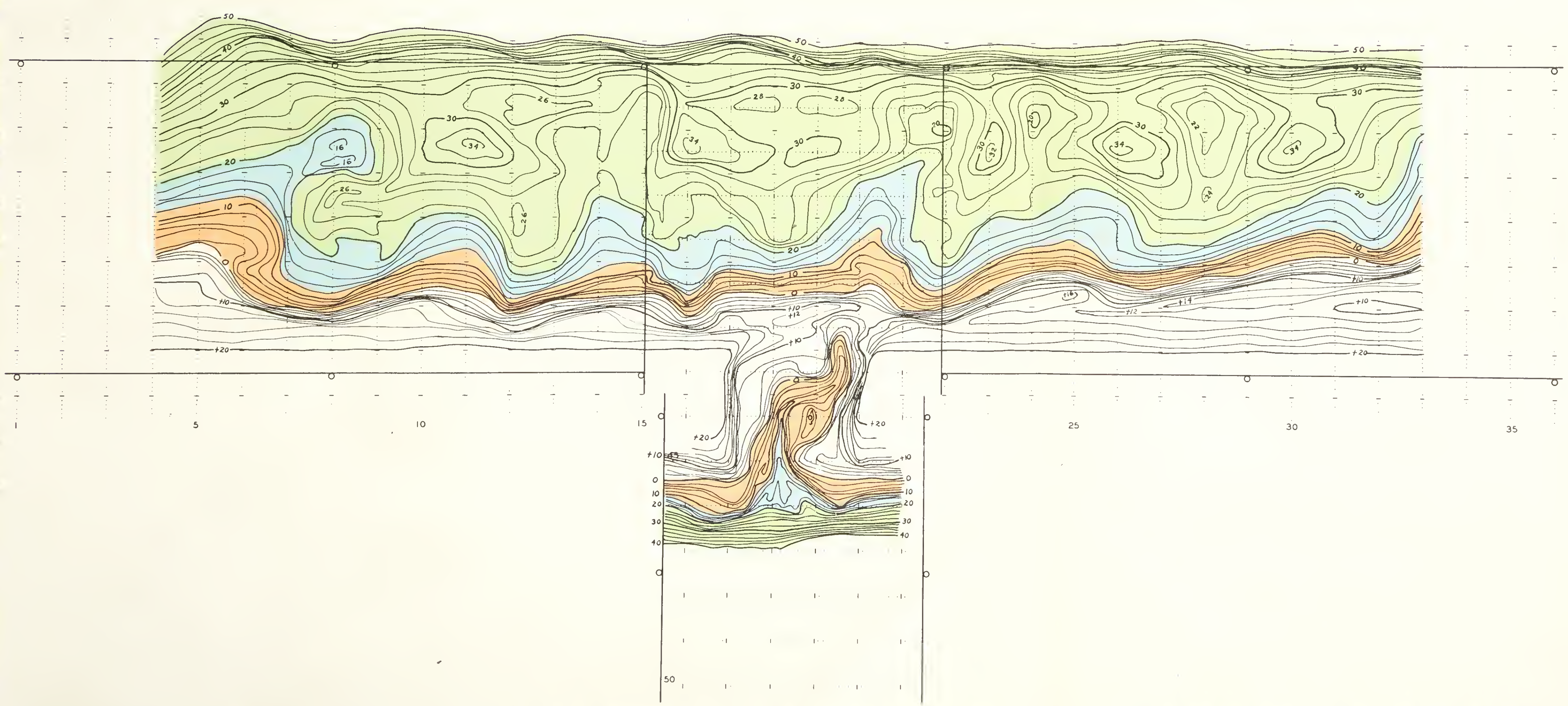
FIGURE 4
HYDROGRAPHIC SURVEY
TEST 1
TER 42 CYCLES OF OPERATION
WITH INLET



--------- Prior Conditions

——————— Present Conditions

a. SCHEMATIC OF GENERAL INLET CHANGES PRIOR TO CLOSURE.

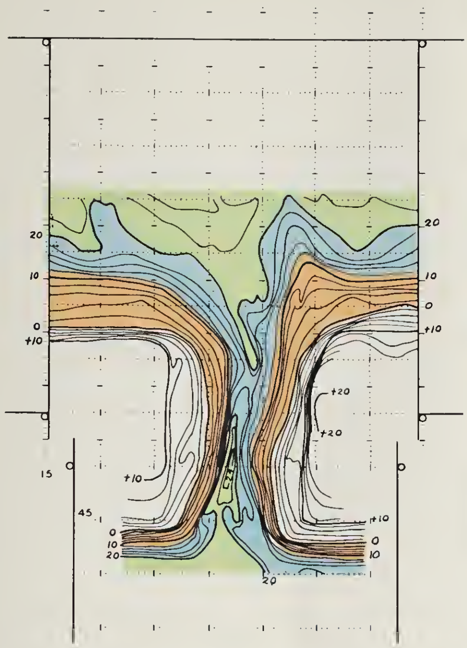


ABOVE 0	−12 TO −20
0 TO −12	BELOW −20

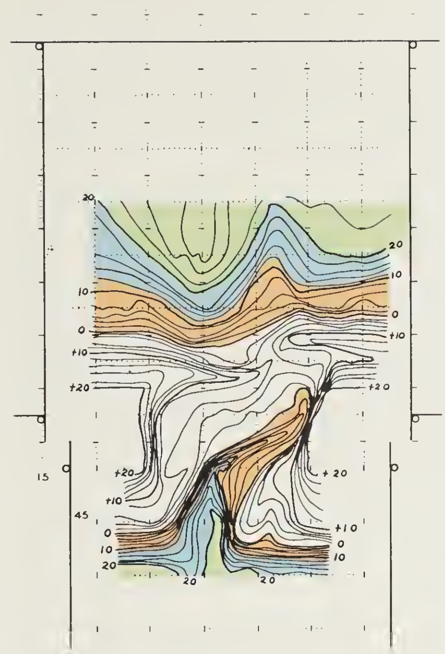
ELEVATIONS IN HUNDREDTHS OF FEET MTL.
CONTOUR INTERVAL 0.02

SCALE IN FEET
2 0 2 4 6 8 10

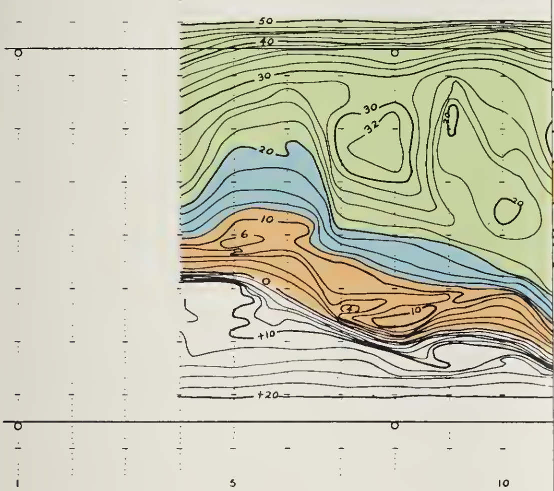
FIGURE 4
HYDROGRAPHIC SURVEY
TEST 1
AFTER 42 CYCLES OF OPERATION
WITH INLET



AFTER 6 CYCLES



AFTER 30 CYCLES



ABOVE 0	-12 TO -20
0 TO -12	BELOW -20

EVATIONS IN HUNDREDTHS OF FEET MTL.
NTOUR INTERVAL 0.02

SCALE IN FEET
2 0 2 4 6 8 10

FIGURE 5
HYDROGRAPHIC SURVEYS
TEST 2

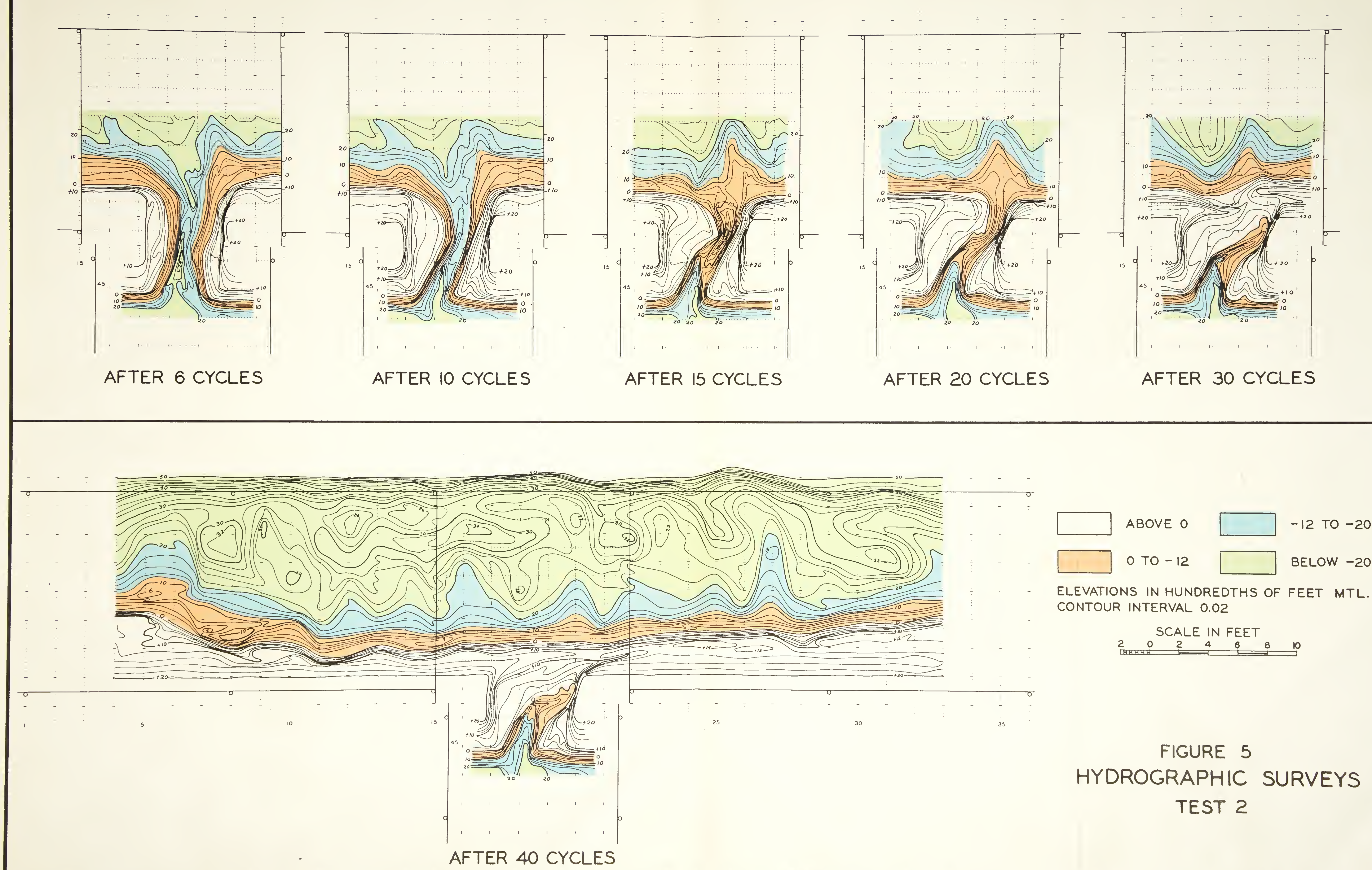


FIGURE 5
HYDROGRAPHIC SURVEYS
TEST 2

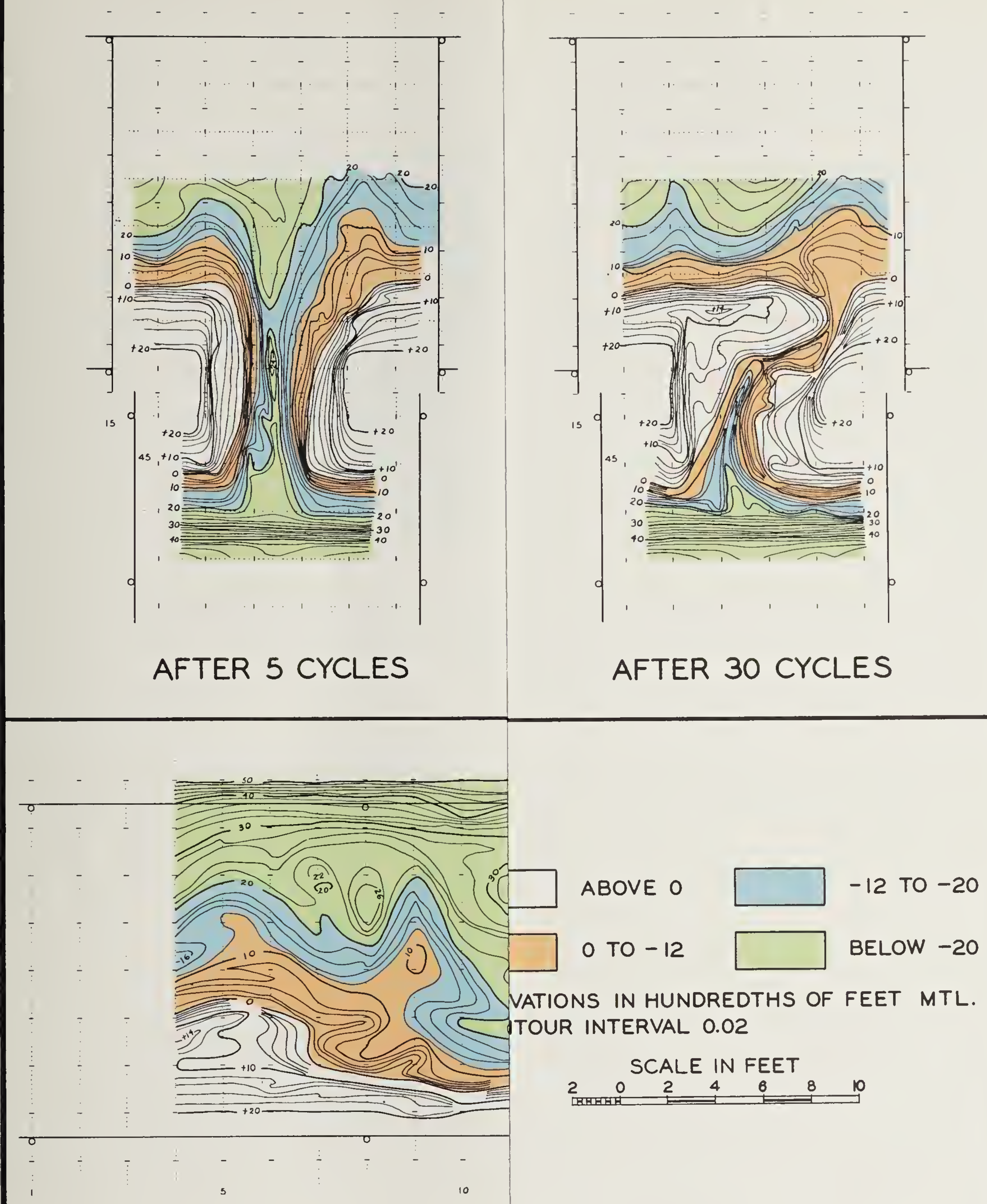


FIGURE 6
HYDROGRAPHIC SURVEYS
TEST 3

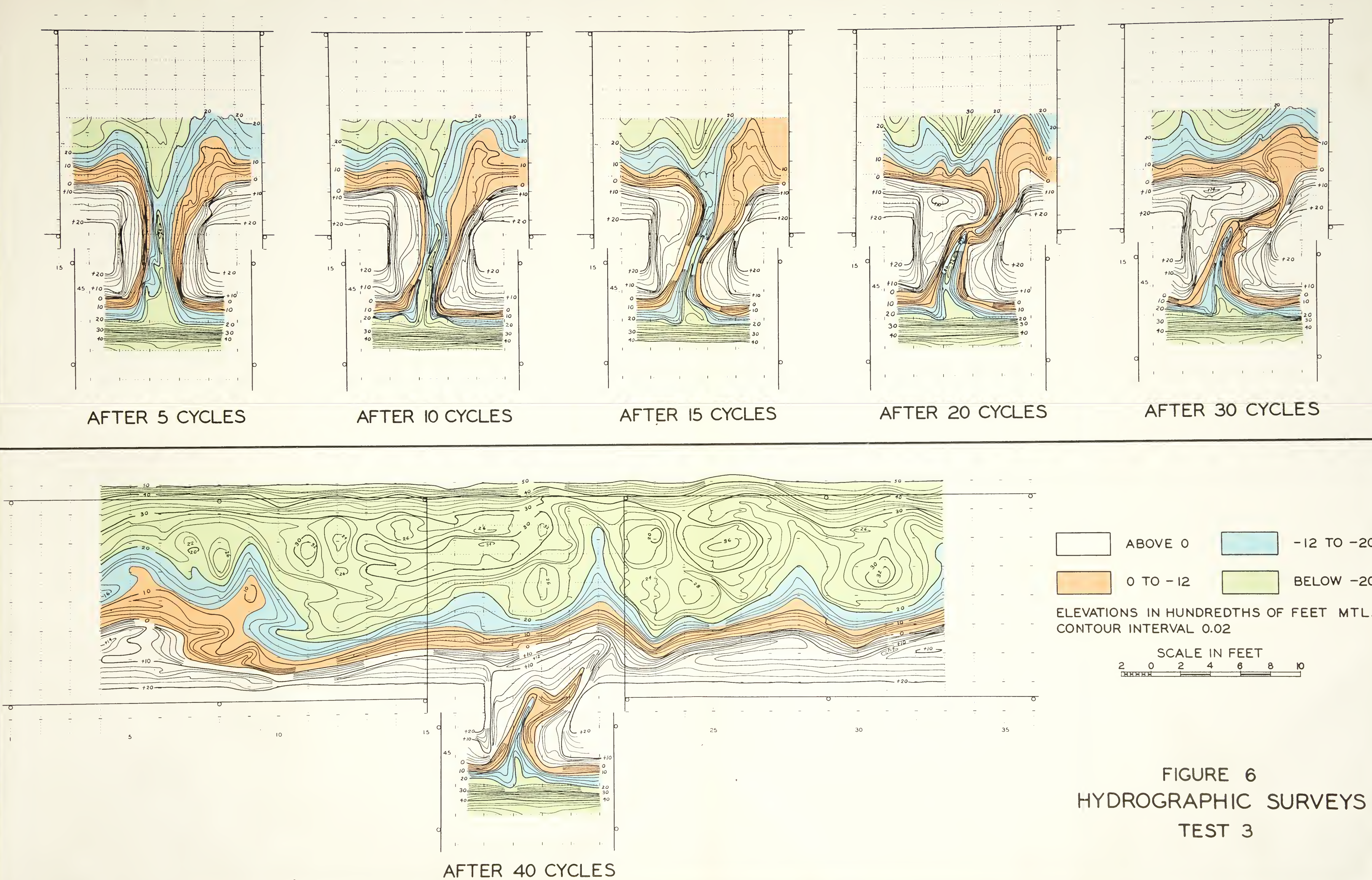
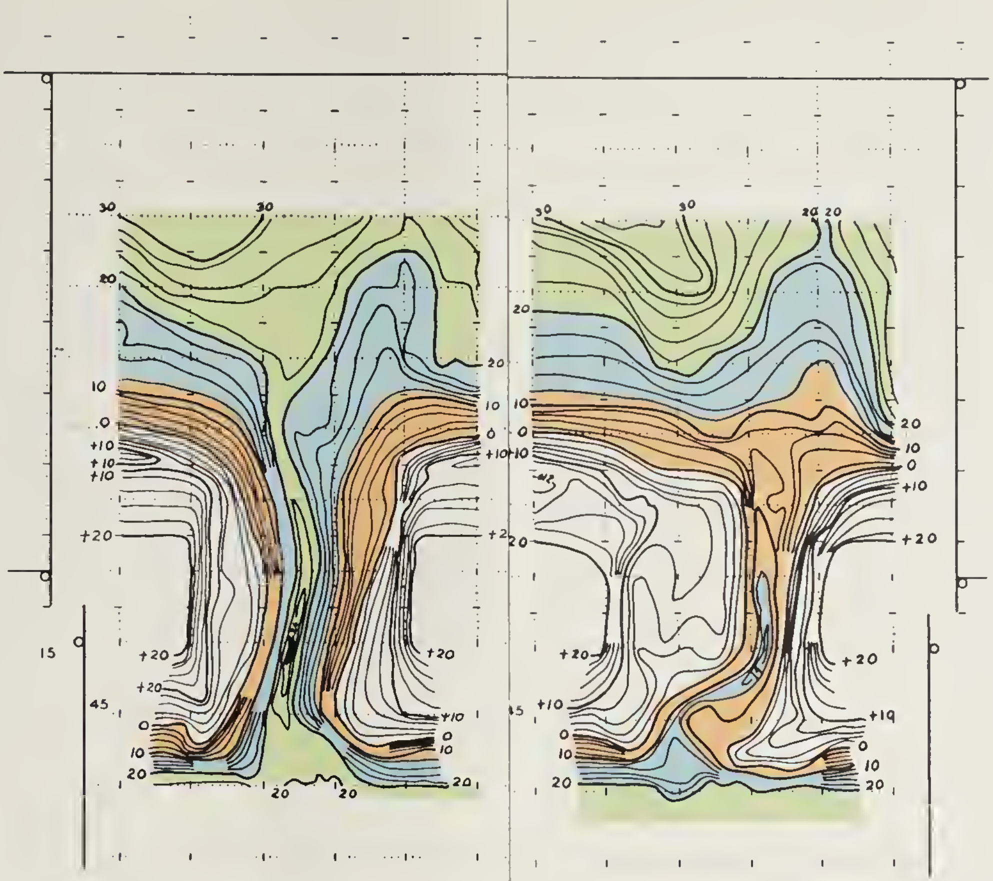
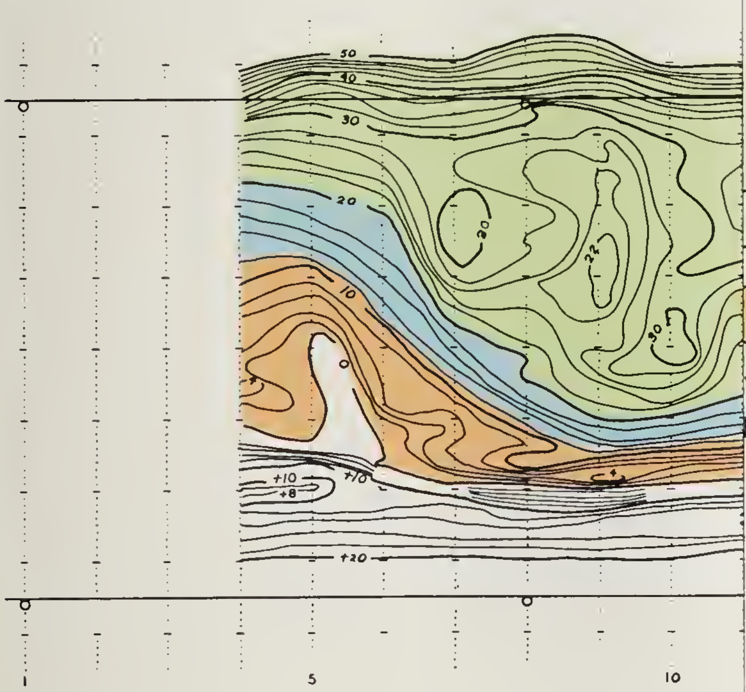


FIGURE 6
HYDROGRAPHIC SURVEYS
TEST 3



AFTER 10 CYCLES AFTER 40 CYCLES



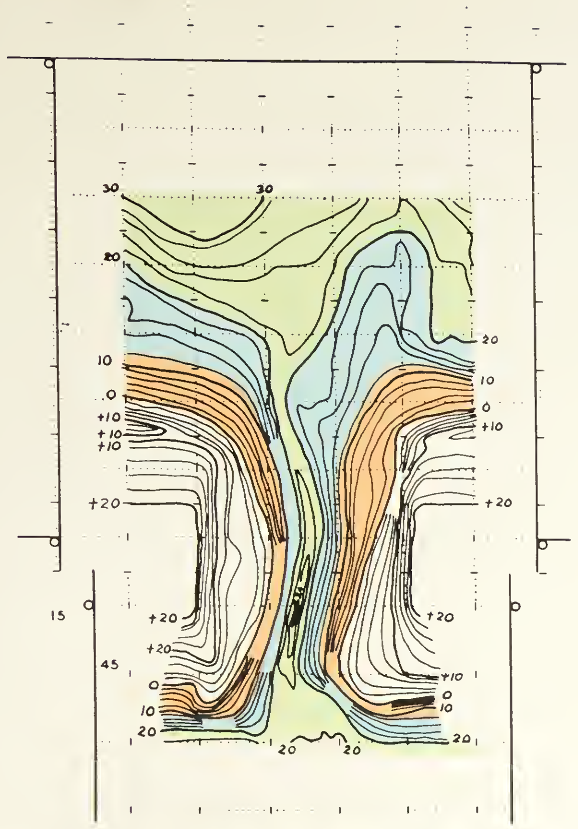
ABOVE 0 | -12 TO -20

0 TO - 12 | BELOW -20

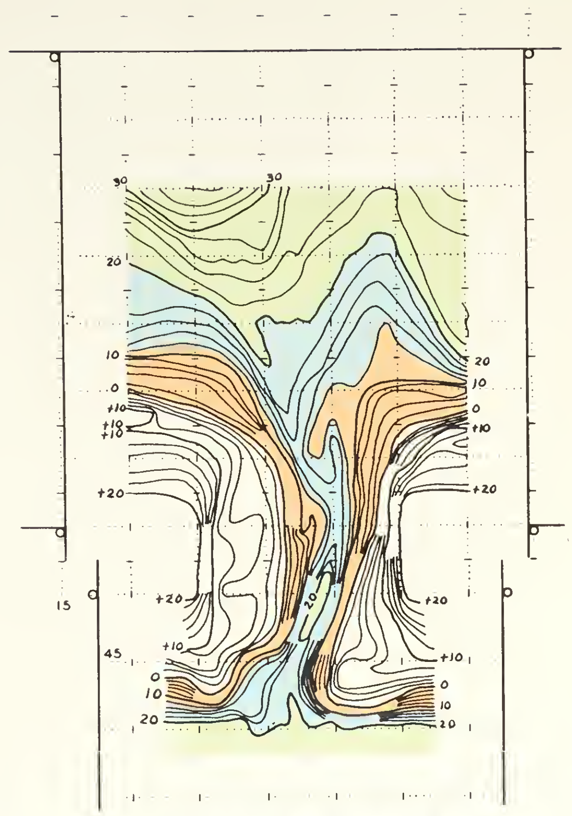
VATIONS IN HUNDREDTHS OF FEET MTL.
TOUR INTERVAL 0.02

SCALE IN FEET
2 0 2 4 6 8 10

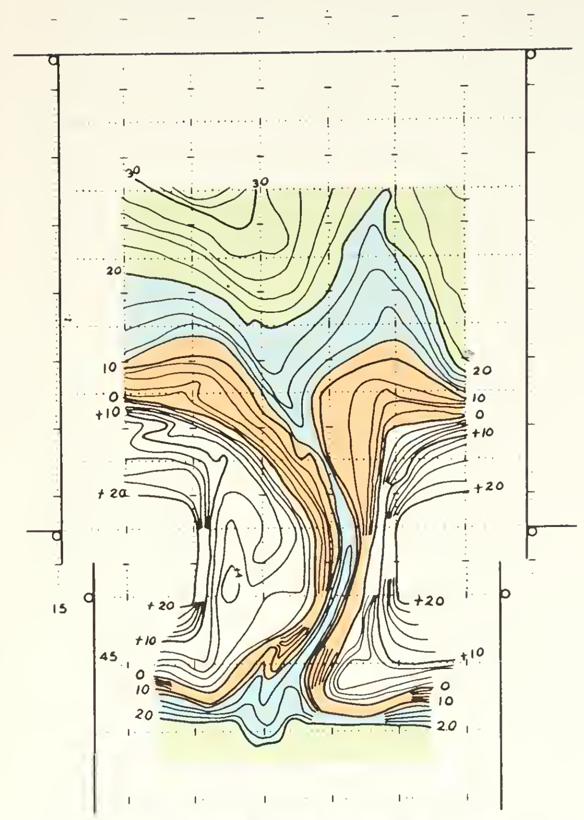
FIGURE 7A
HYDROGRAPHIC SURVEYS
TEST 4



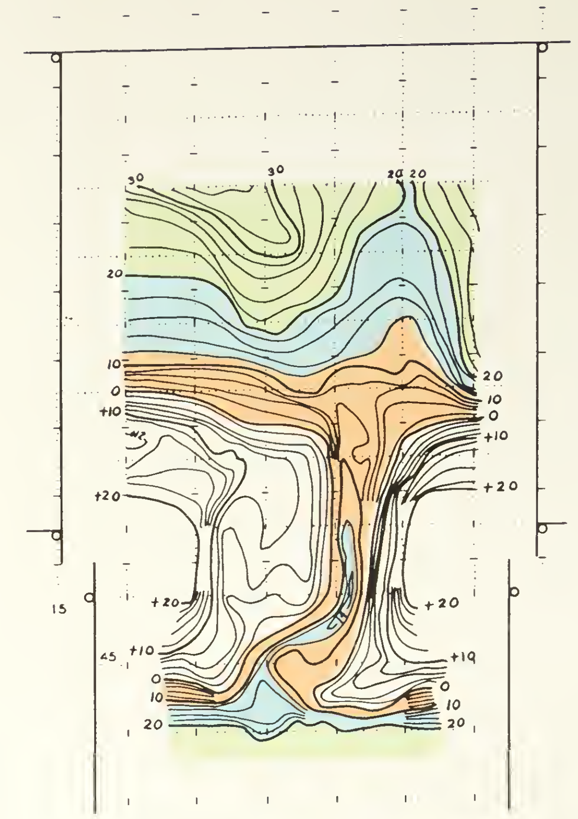
AFTER 10 CYCLES



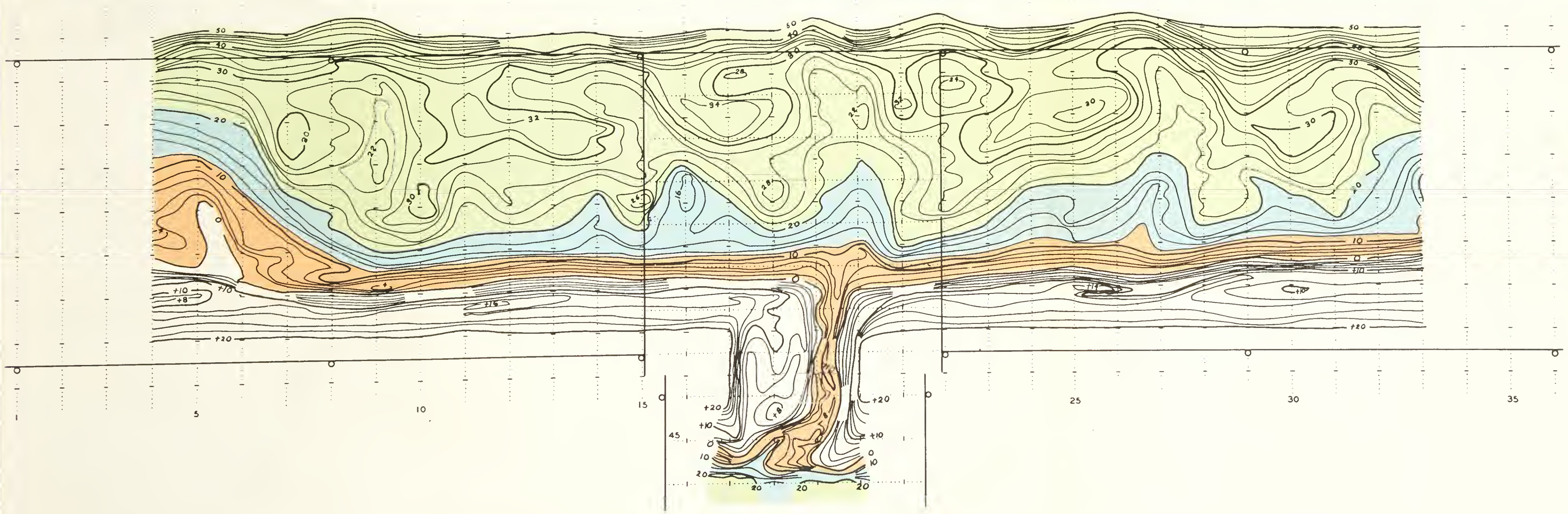
AFTER 20 CYCLES



AFTER 30 CYCLES



AFTER 40 CYCLES



AFTER 50 CYCLES

ABOVE 0   -12 TO -20

0 TO -12   BELOW -20

ELEVATIONS IN HUNDREDTHS OF FEET MTL.
CONTOUR INTERVAL 0.02

SCALE IN FEET
2 0 2 4 6 8 10

FIGURE 7A
HYDROGRAPHIC SURVEYS
TEST 4

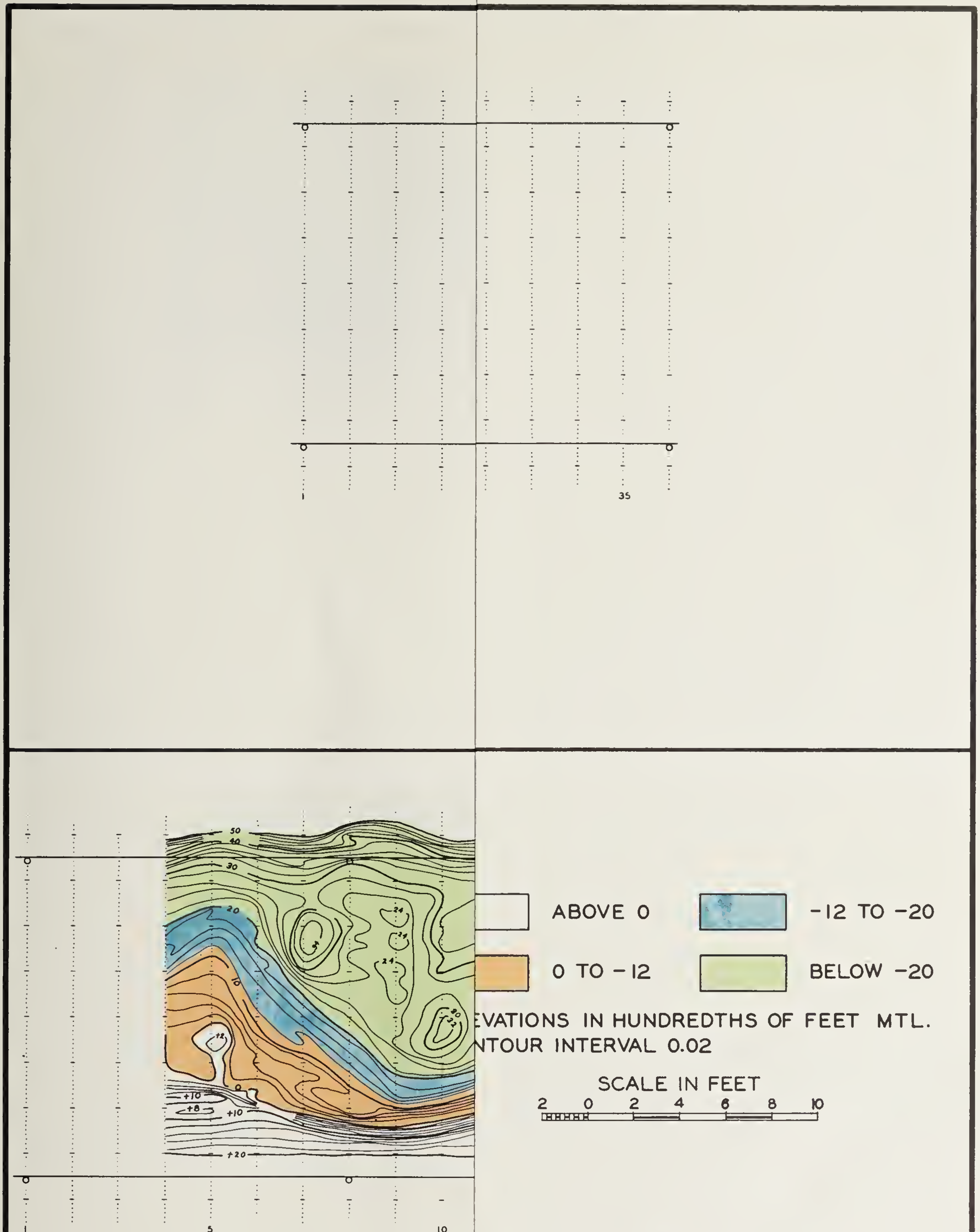
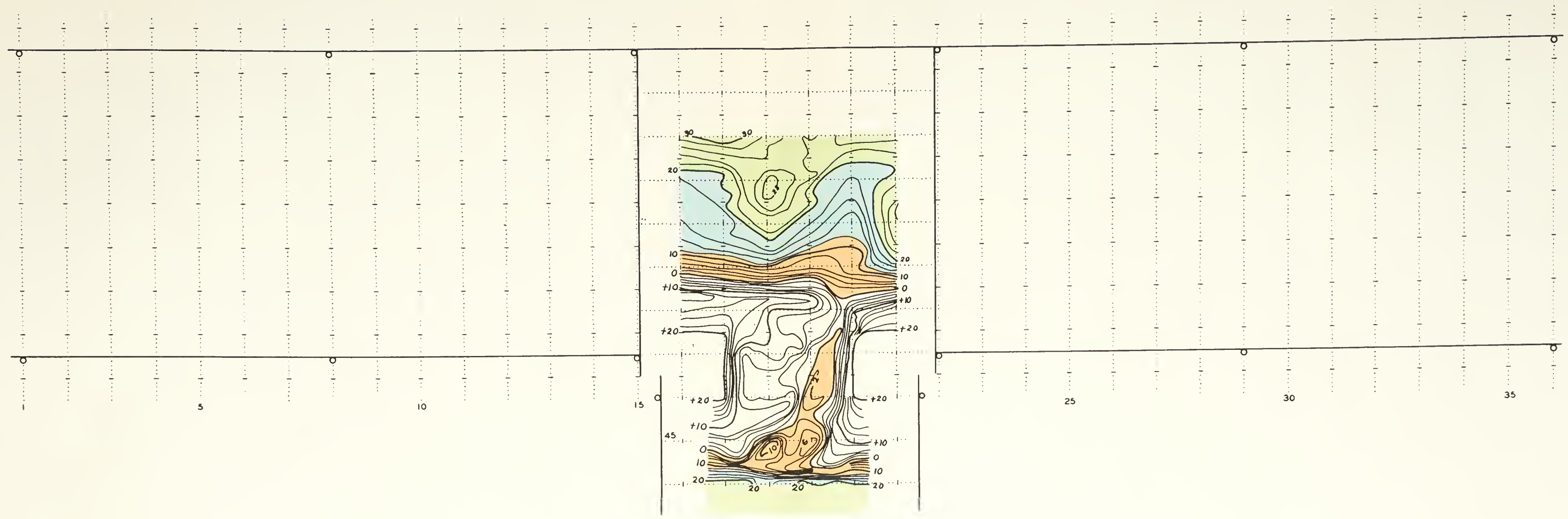
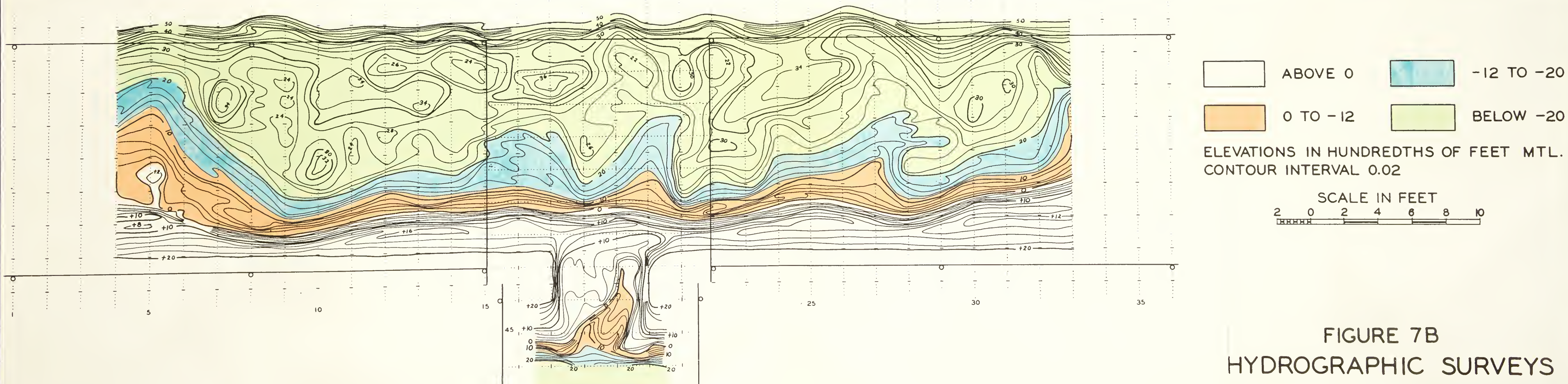


FIGURE 7B
HYDROGRAPHIC SURVEYS
TEST 4



AFTER 60 CYCLES



AFTER 70 CYCLES

FIGURE 7B
HYDROGRAPHIC SURVEYS
TEST 4

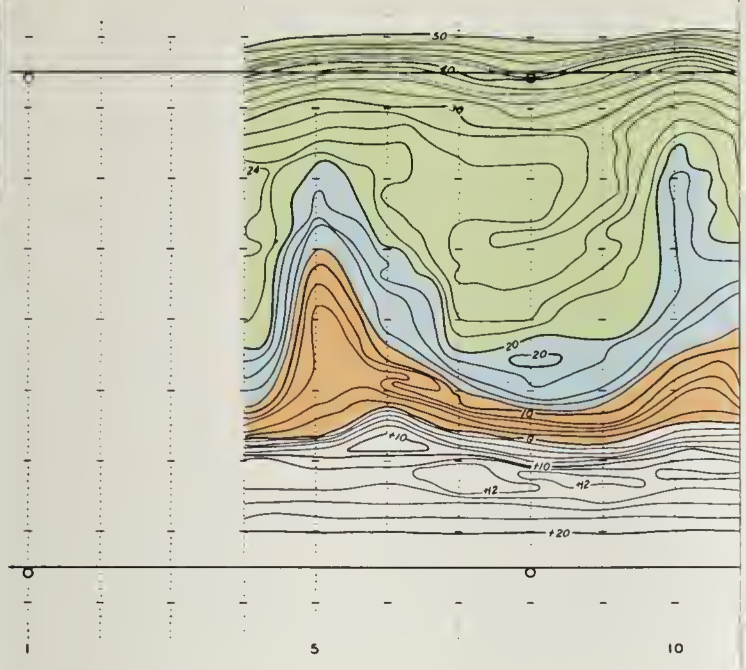


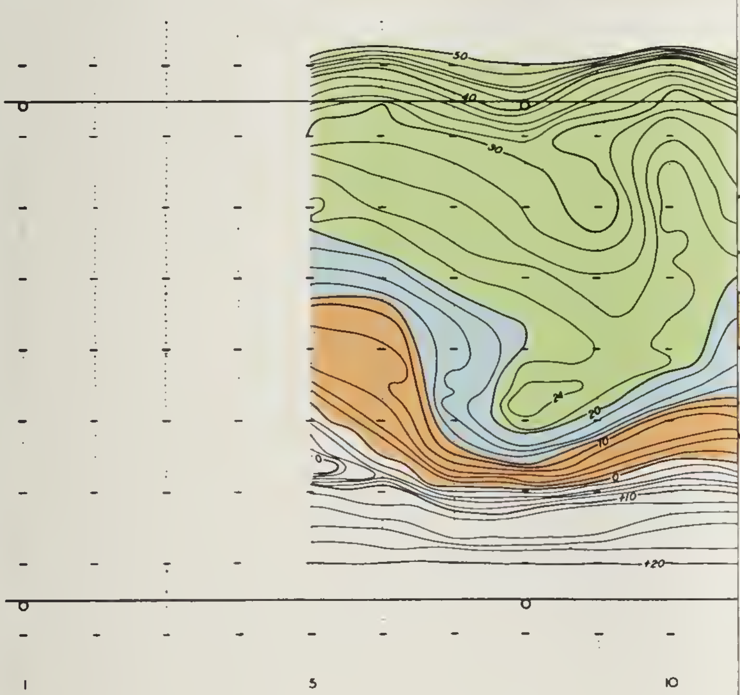
FIGURE 8

HYDROGRAPHIC SURVEY

TEST 5

INLET AS INITIALLY

T THROUGH STABILIZED BEACH



ABOVE 0

-12 TO -20

0 TO -12

BELOW -20

VATIONS IN HUNDREDTHS OF FEET MTL.

NTOUR INTERVAL 0.02

SCALE IN FEET

2 0 2 4 6 8 10

FIGURE 9

HYDROGRAPHIC SURVEY

TEST 5

TER 60 CYCLES OF OPERATION

WITH INLET

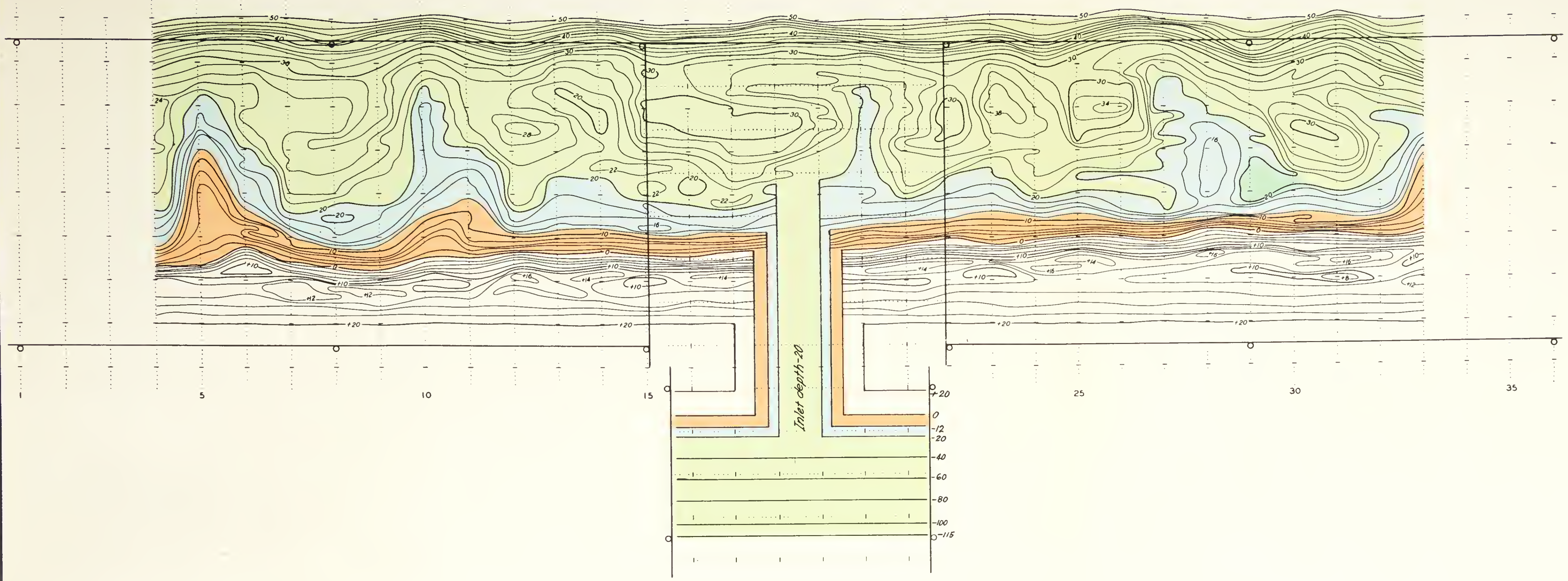
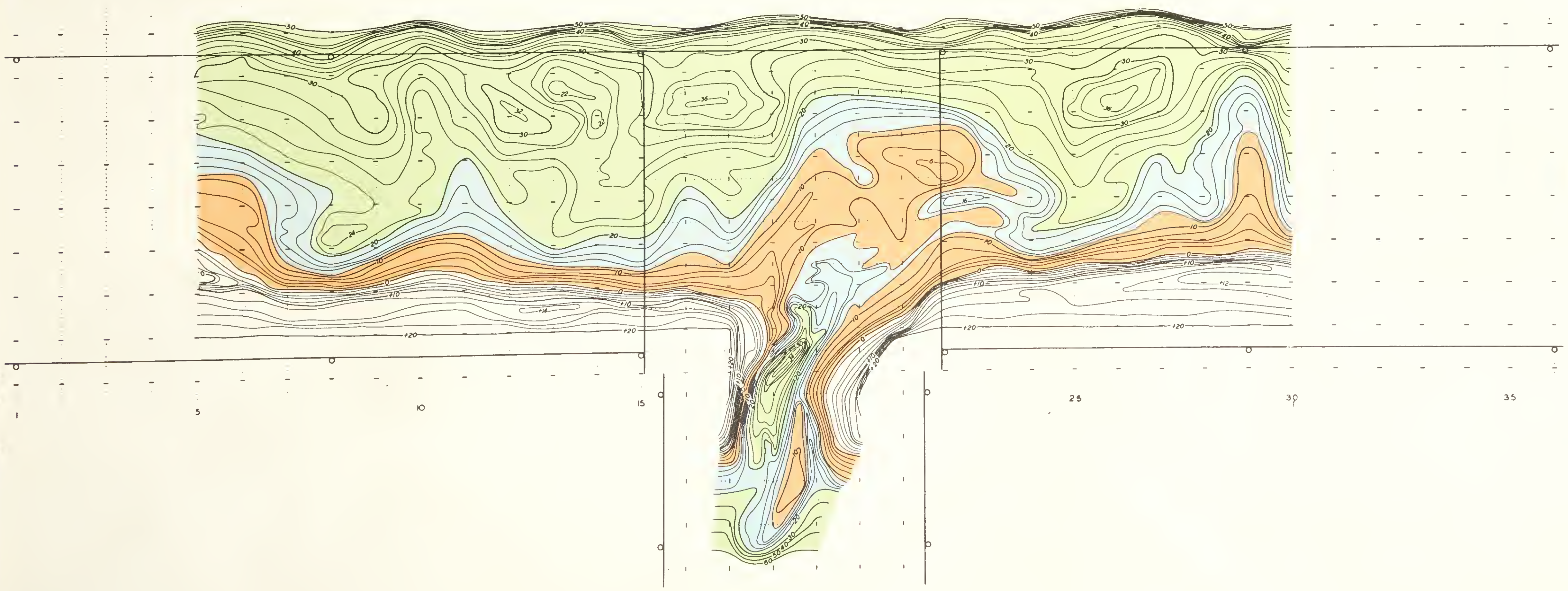


FIGURE 8
HYDROGRAPHIC SURVEY
TEST 5
INLET AS INITIALLY
CUT THROUGH STABILIZED BEACH



ABOVE 0 — -12 TO -20
0 TO -12 — BELOW -20

ELEVATIONS IN HUNDREDTHS OF FEET MTL.
CONTOUR INTERVAL 0.02

SCALE IN FEET
2 0 2 4 6 8 10

FIGURE 9
HYDROGRAPHIC SURVEY
TEST 5
AFTER 60 CYCLES OF OPERATION
WITH INLET

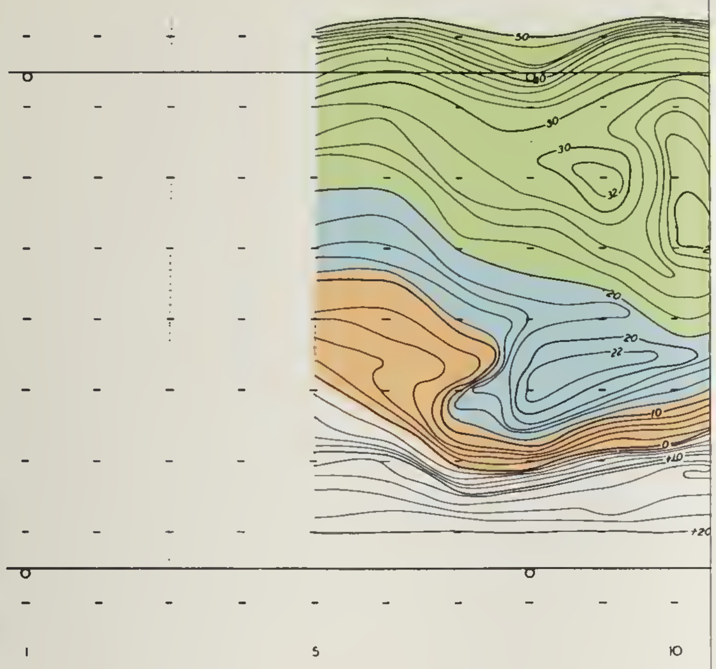
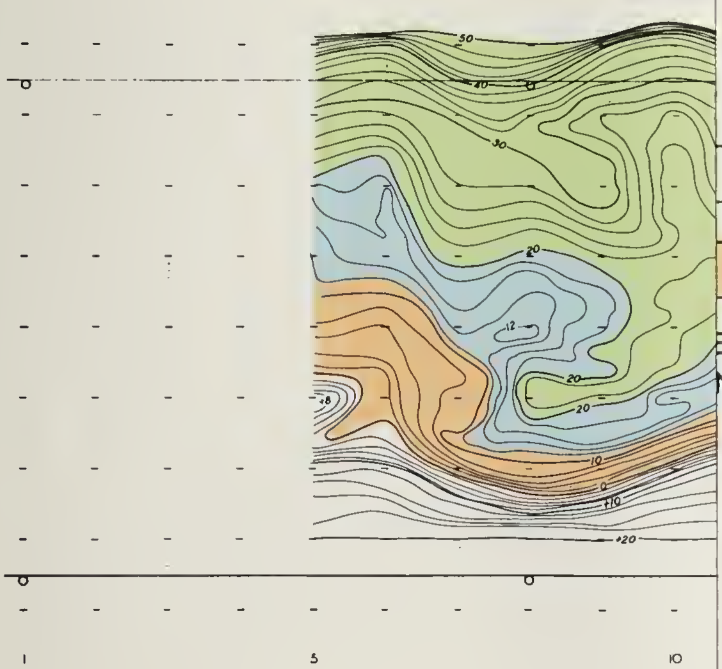


FIGURE 10
HYDROGRAPHIC SURVEY
TEST 5
TER 70 CYCLES OF OPERATION
WITH INLET



	ABOVE 0		-12 TO -20
	0 TO -12		BELOW -20

EVATIONS IN HUNDREDTHS OF FEET MTL.
NTOUR INTERVAL 0.02

SCALE IN FEET
2 0 2 4 6 8 10

FIGURE 11
HYDROGRAPHIC SURVEY
TEST 5
TER 80 CYCLES OF OPERATION
WITH INLET

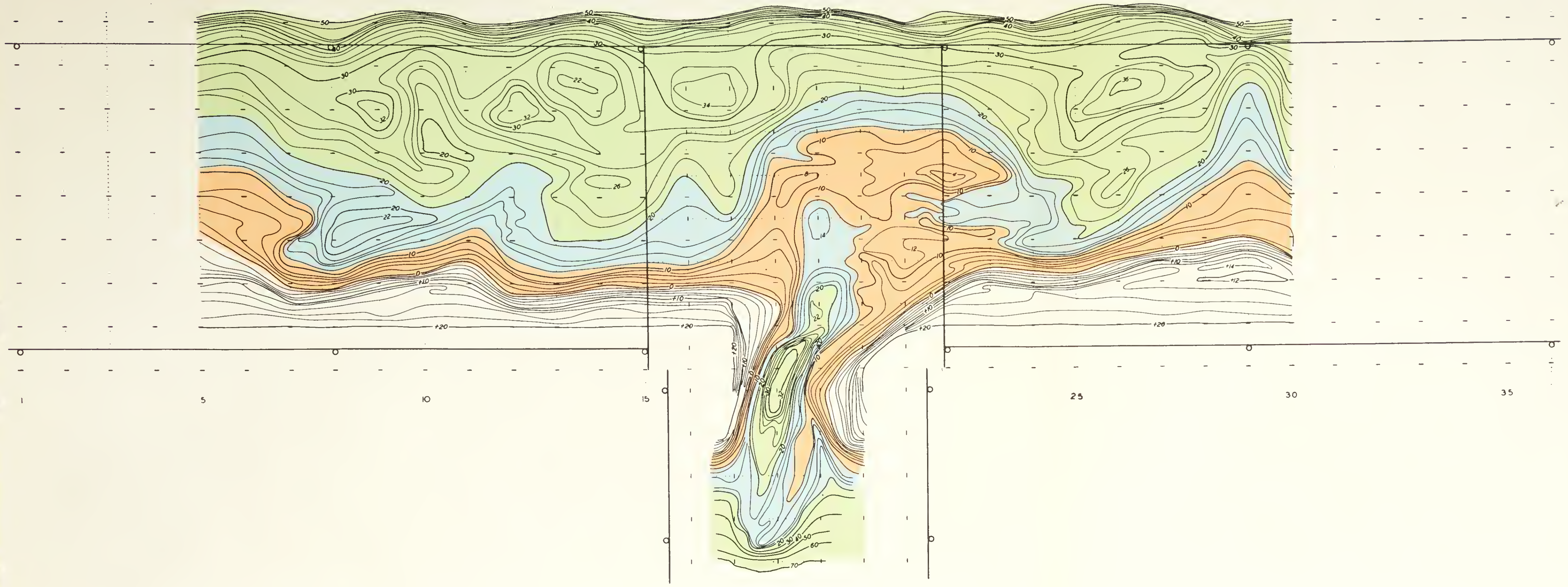
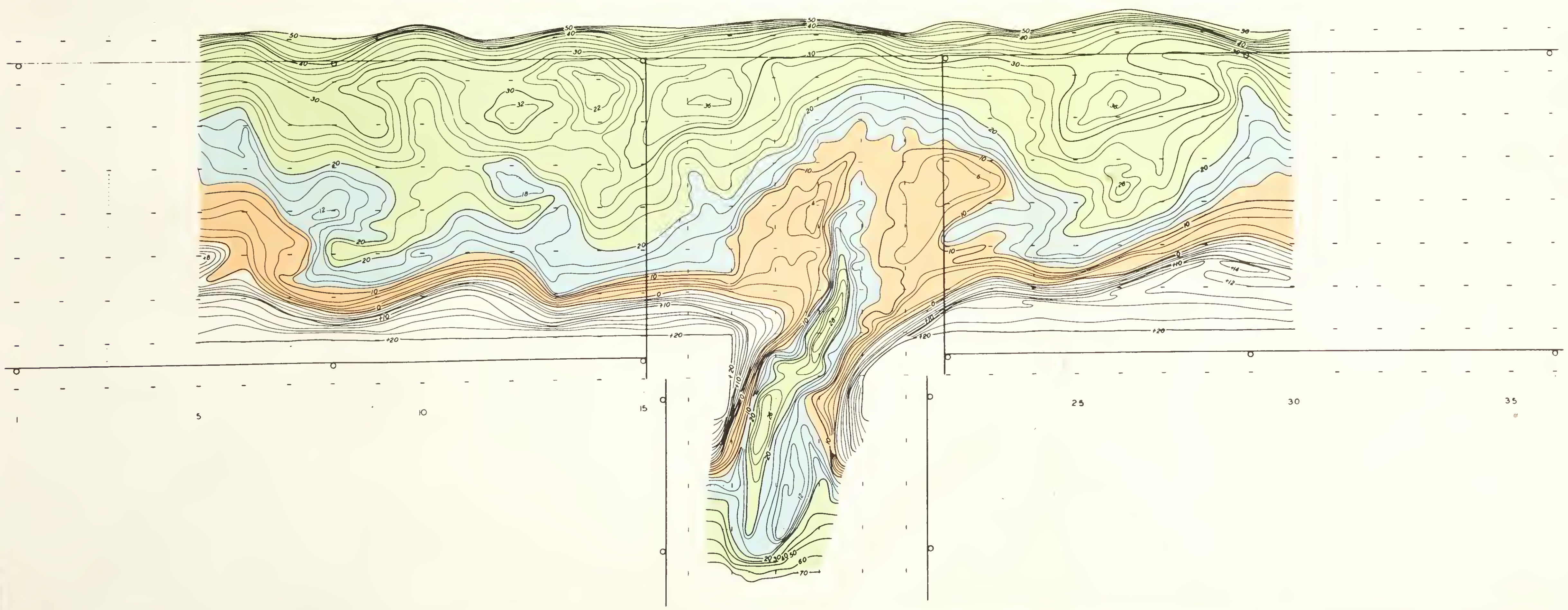


FIGURE 10
HYDROGRAPHIC SURVEY
TEST 5
AFTER 70 CYCLES OF OPERATION
WITH INLET



ABOVE 0
-12 TO -20
0 TO -12
BELOW -20

ELEVATIONS IN HUNDREDTHS OF FEET MTL.
CONTOUR INTERVAL 0.02

SCALE IN FEET
2 0 2 4 6 8 10

FIGURE 11
HYDROGRAPHIC SURVEY
TEST 5
AFTER 80 CYCLES OF OPERATION
WITH INLET

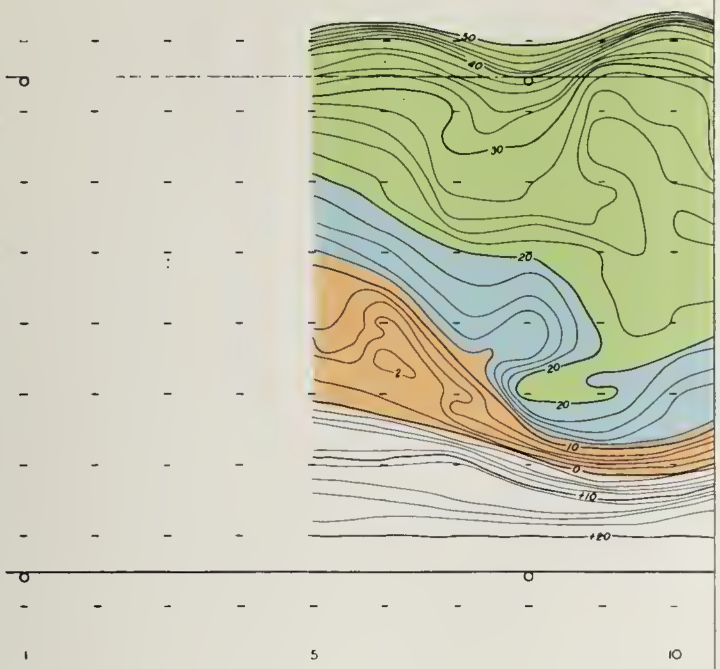


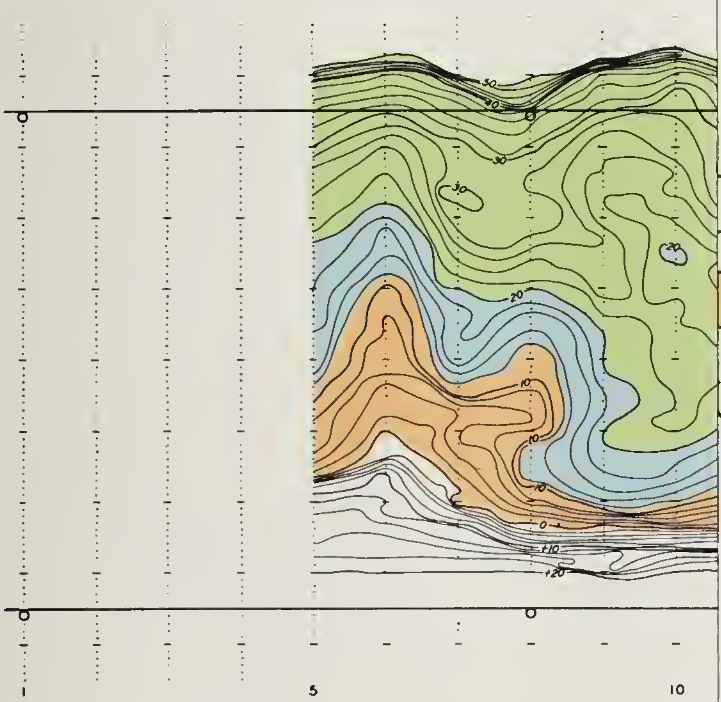
FIGURE 12

HYDROGRAPHIC SURVEY

TEST 5

TER 90 CYCLES OF OPERATION

WITH INLET



ABOVE 0 | -12 TO -20

0 TO -12 | BELOW -20

VATIONS IN HUNDREDTHS OF FEET MTL.

NTOUR INTERVAL 0.02

SCALE IN FEET

2 0 2 4 6 8 10

FIGURE 13

HYDROGRAPHIC SURVEY

TEST 5

TER 120 CYCLES OF OPERATION

WITH INLET

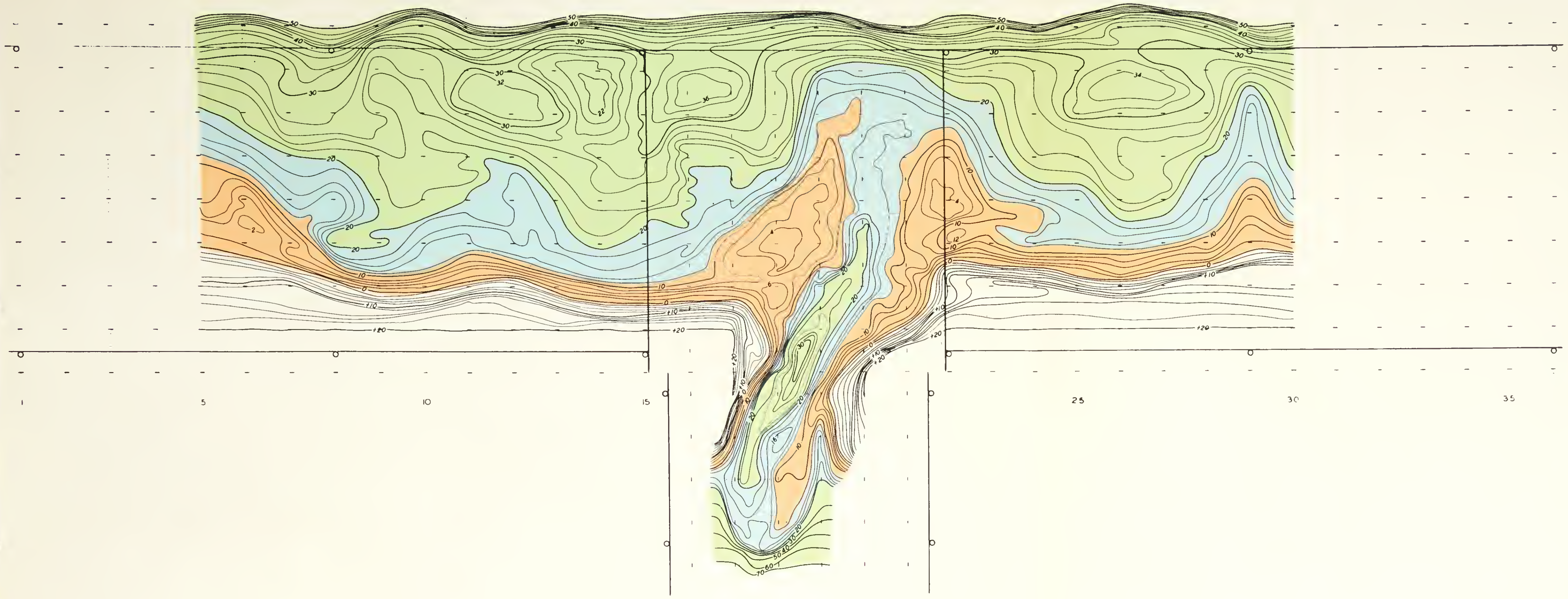
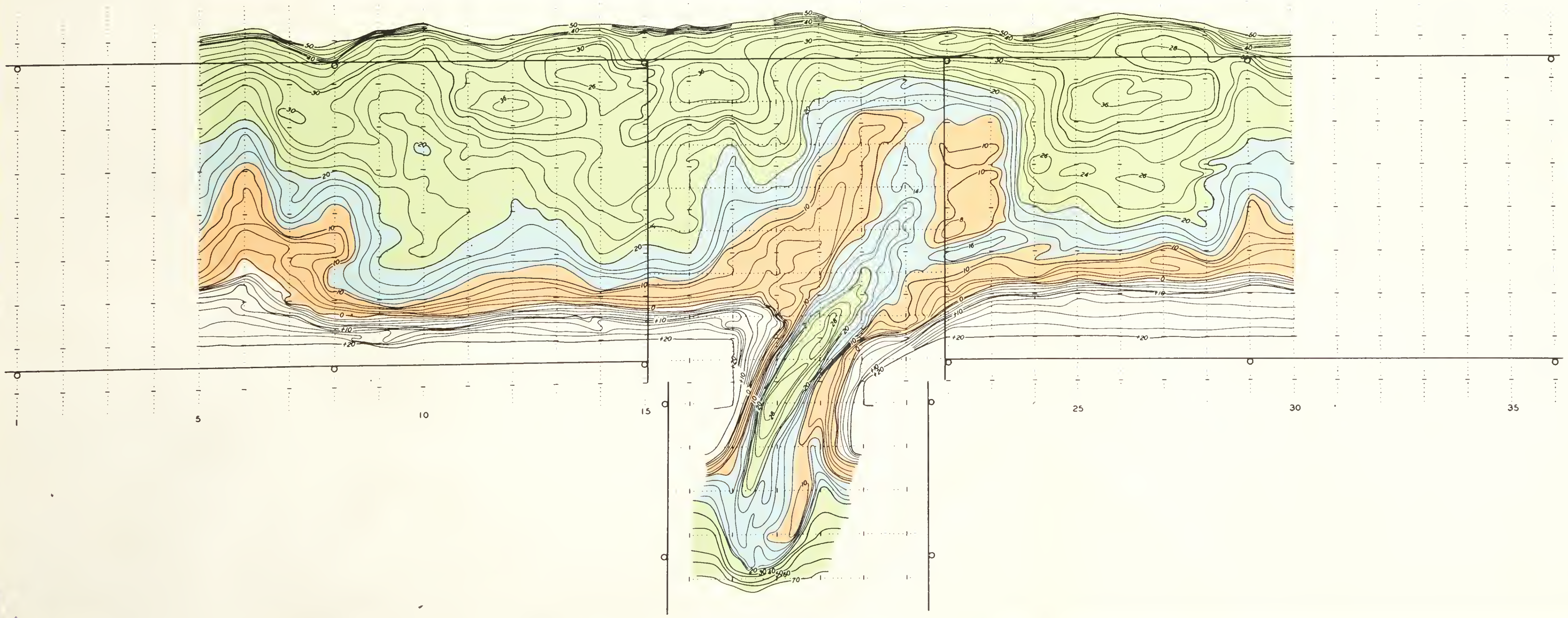


FIGURE 12
HYDROGRAPHIC SURVEY
TEST 5
AFTER 90 CYCLES OF OPERATION
WITH INLET



ABOVE 0
-12 TO -20
0 TO -12
BELOW -20

ELEVATIONS IN HUNDREDTHS OF FEET MTL.
CONTOUR INTERVAL 0.02

SCALE IN FEET
2 0 2 4 6 8 10

FIGURE 13
HYDROGRAPHIC SURVEY
TEST 5
AFTER 120 CYCLES OF OPERATION
WITH INLET

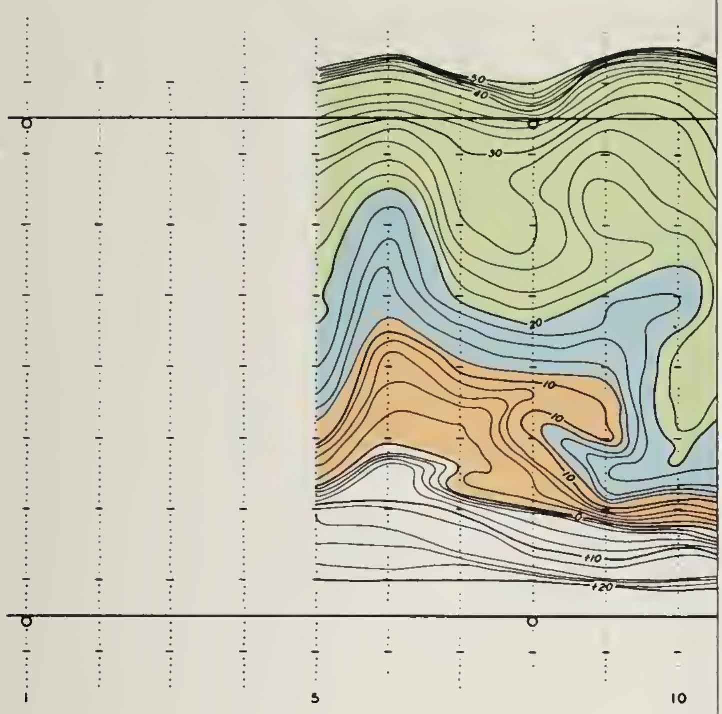
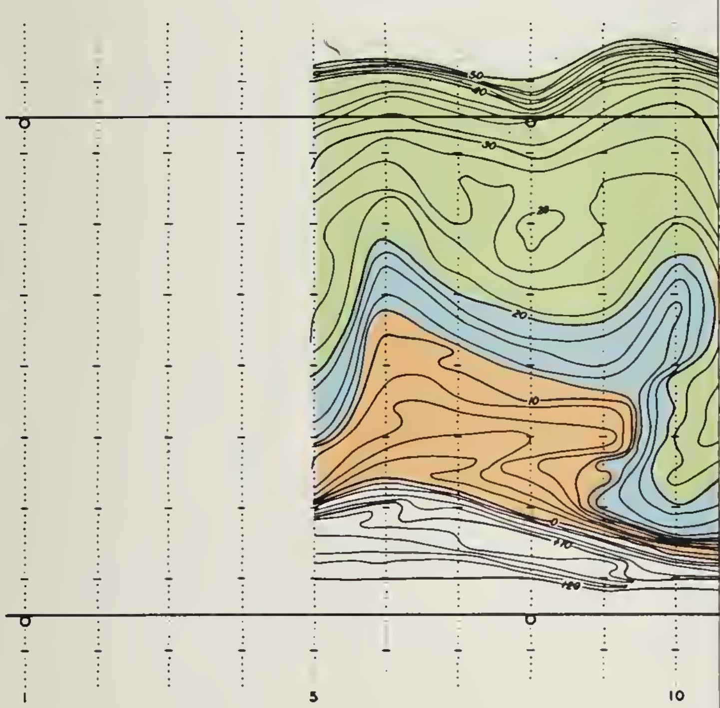


FIGURE 14

ıYDROGRAPHIC SURVEY

TEST 5

ʼER 150 CYCLES OF OPERATION
WITH INLET



ABOVE 0	-12 TO -20
0 TO - 12	BELOW -20

VATIONS IN HUNDREDTHS OF FEET MTL.
ITOUR INTERVAL 0.02

SCALE IN FEET
2 0 2 4 6 8 10

FIGURE 15

ıYDROGRAPHIC SURVEY

TEST 5

ʼER 180 CYCLES OF OPERATION
WITH INLET

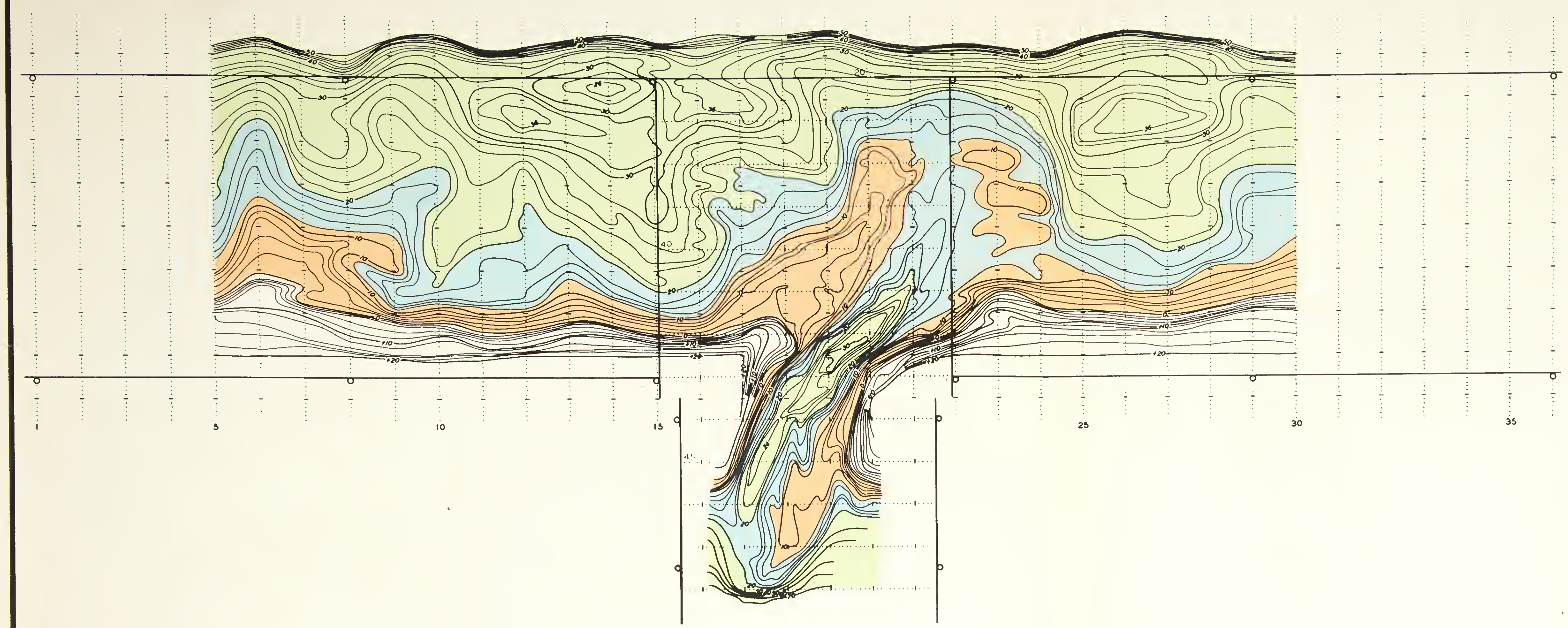
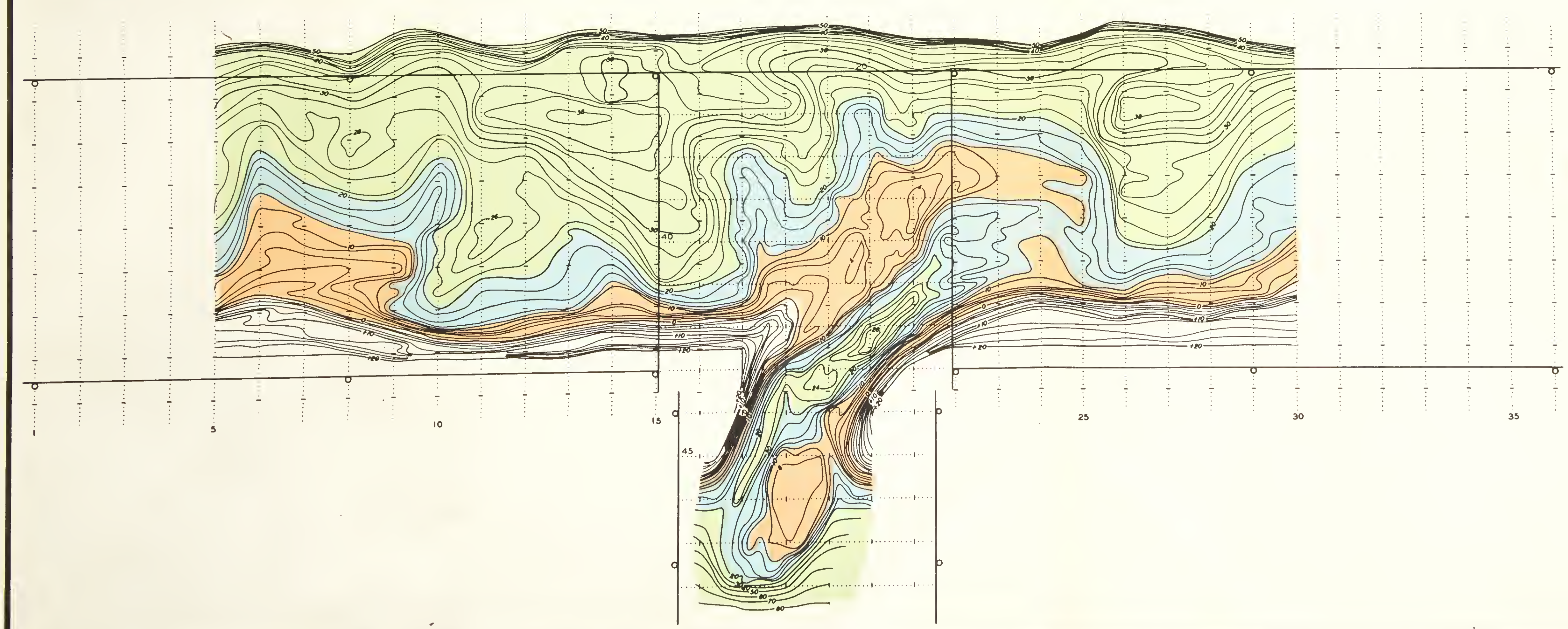


FIGURE 14
HYDROGRAPHIC SURVEY
TEST 5
AFTER 150 CYCLES OF OPERATION
WITH INLET



ABOVE 0
-12 TO -20
0 TO -12
BELOW -20

ELEVATIONS IN HUNDREDTHS OF FEET MTL.
CONTOUR INTERVAL 0.02

SCALE IN FEET
2 0 2 4 6 8 10

FIGURE 15
HYDROGRAPHIC SURVEY
TEST 5
AFTER 180 CYCLES OF OPERATION
WITH INLET

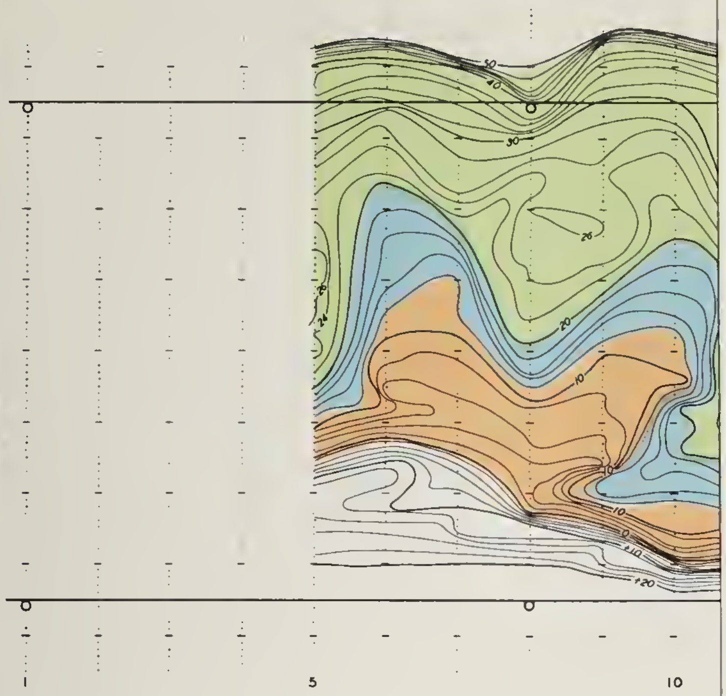
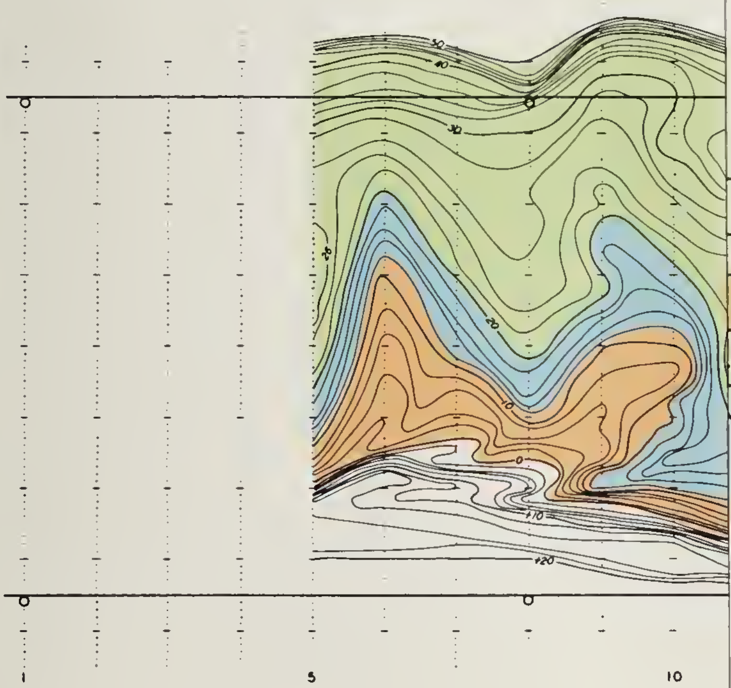


FIGURE 16

HYDROGRAPHIC SURVEY

TEST 5

TER 200 CYCLES OF OPERATION
WITH INLET



ABOVE 0 | -12 TO -20

0 TO - 12 | BELOW -20

VATIONS IN HUNDREDTHS OF FEET MTL.
NTOUR INTERVAL 0.02

SCALE IN FEET
2 0 2 4 6 8 10

FIGURE 17

HYDROGRAPHIC SURVEY

TEST 5

TER 210 CYCLES OF OPERATION
WITH INLET

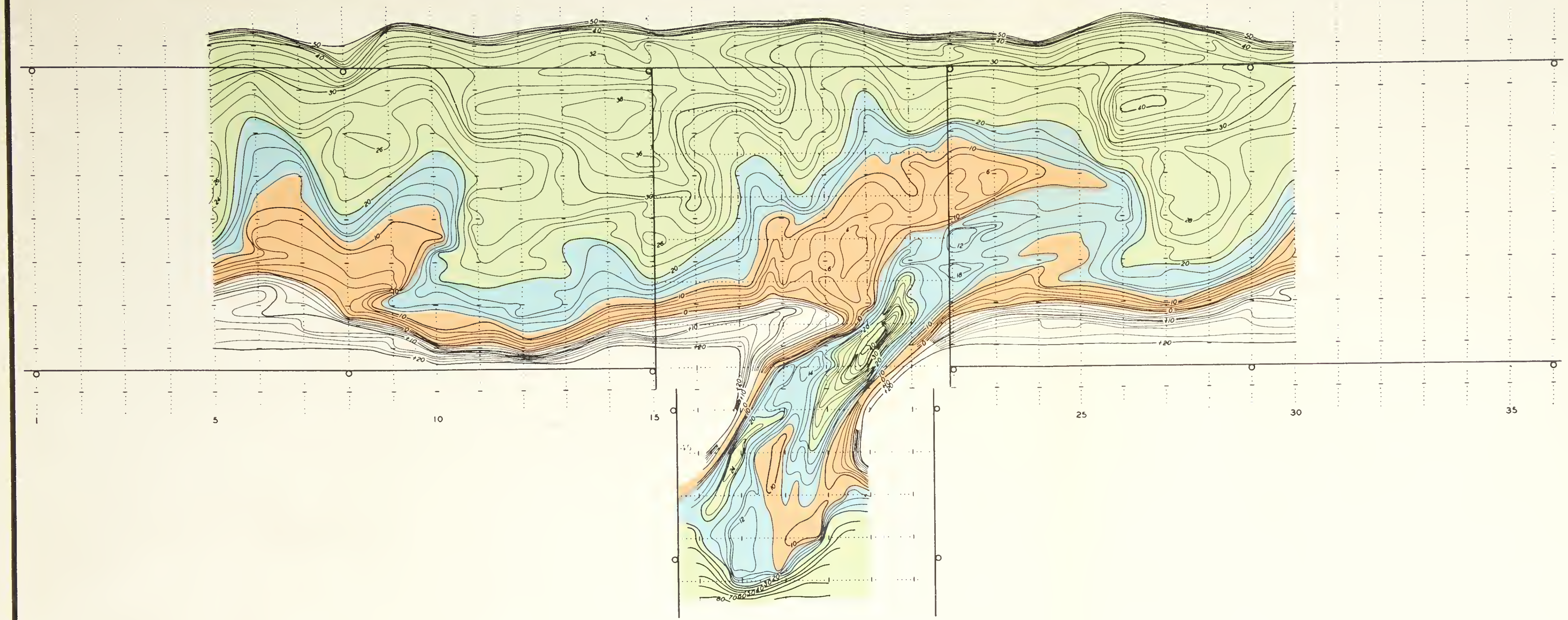


FIGURE 16
HYDROGRAPHIC SURVEY
TEST 5
AFTER 200 CYCLES OF OPERATION
WITH INLET

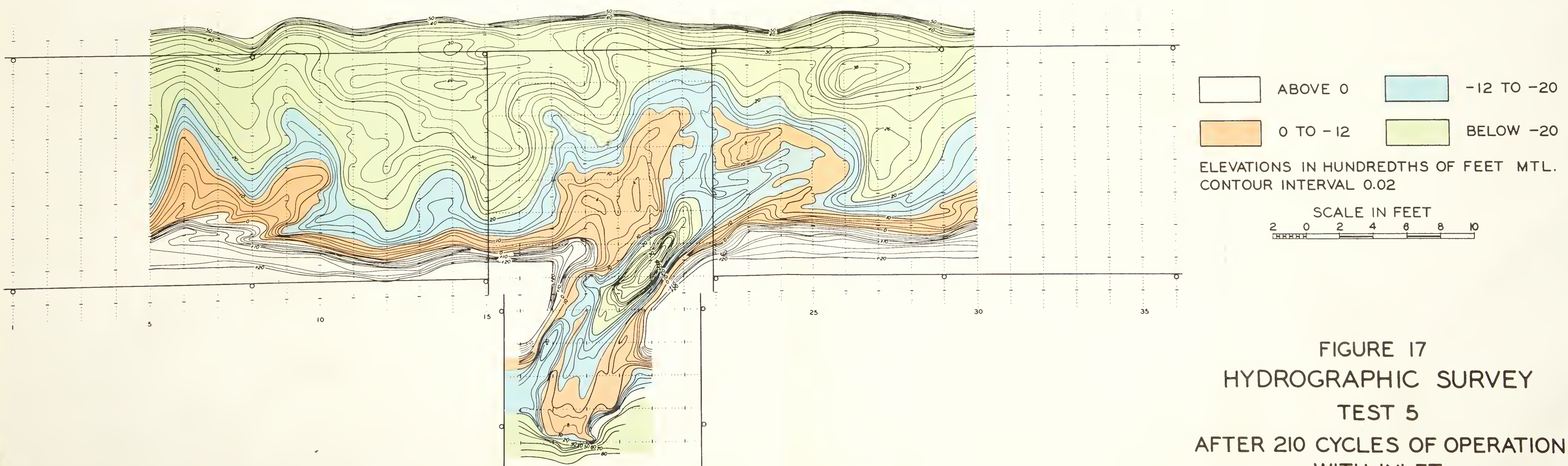


FIGURE 17
HYDROGRAPHIC SURVEY
TEST 5
AFTER 210 CYCLES OF OPERATION
WITH INLET

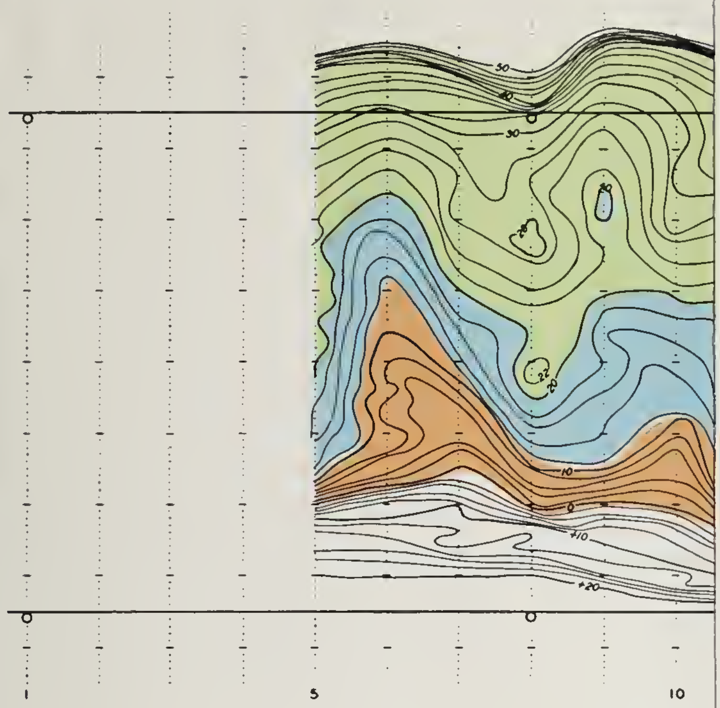


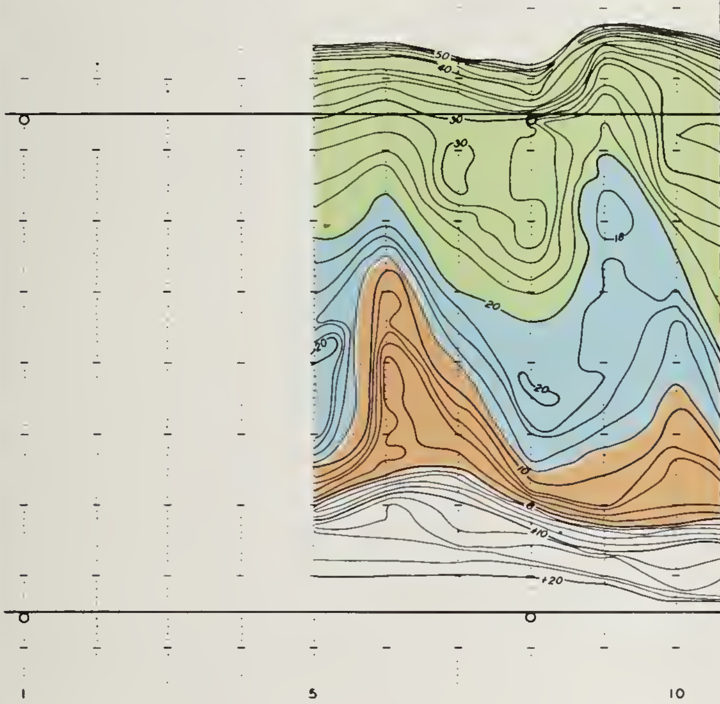
FIGURE 18

HYDROGRAPHIC SURVEY

TEST 5

TER 240 CYCLES OF OPERATION

WITH INLET



ABOVE 0	-12 TO -20
0 TO -12	BELOW -20

EVATIONS IN HUNDREDTHS OF FEET MTL.

NTOUR INTERVAL 0.02

SCALE IN FEET

2 0 2 4 6 8 10

FIGURE 19

HYDROGRAPHIC SURVEY

TEST 5

TER 270 CYCLES OF OPERATION

WITH INLET

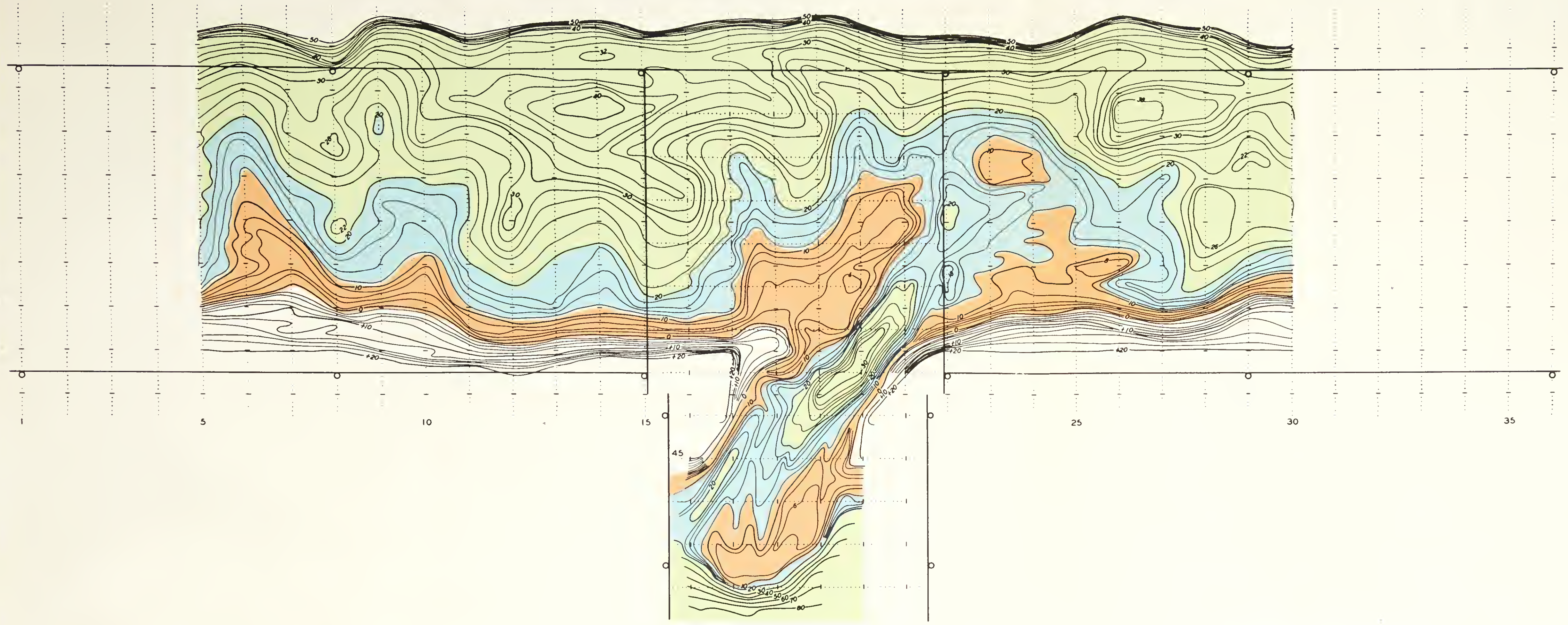
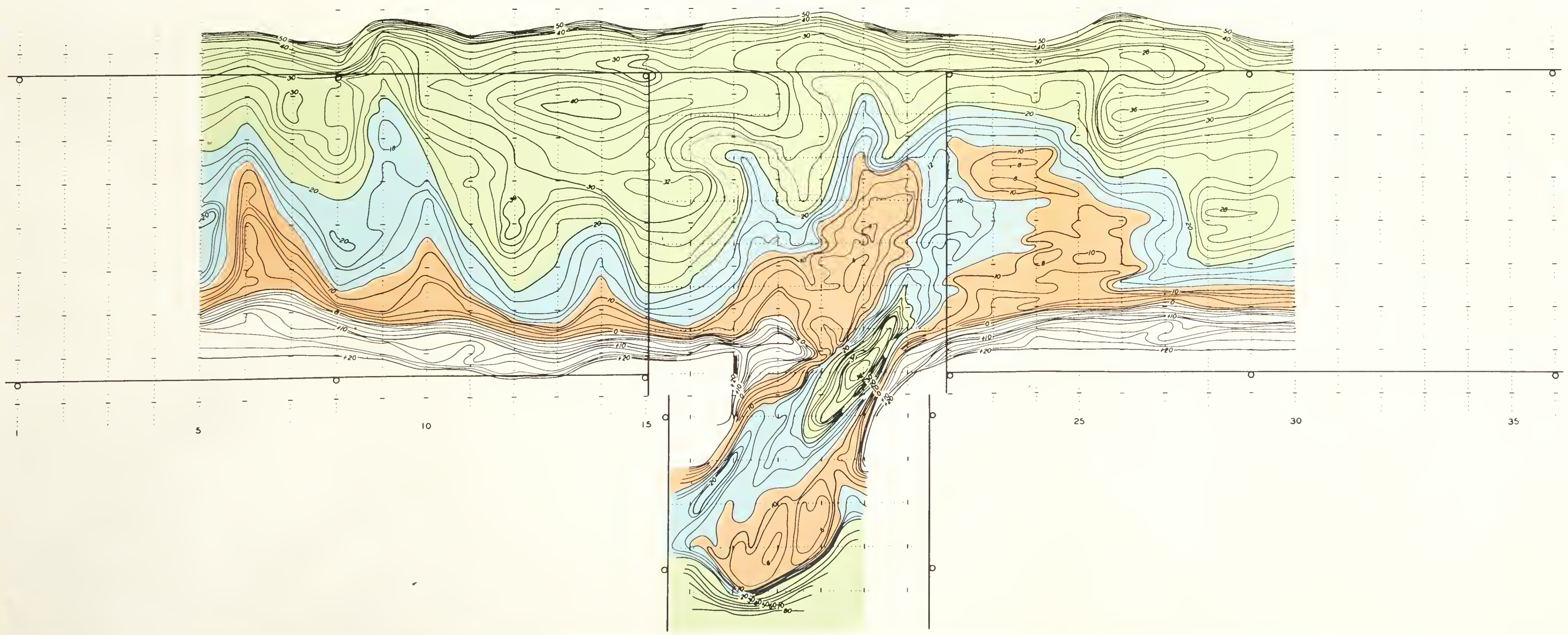


FIGURE 18
HYDROGRAPHIC SURVEY
TEST 5
AFTER 240 CYCLES OF OPERATION
WITH INLET



ABOVE 0

0 TO − 12

−12 TO −20

BELOW −20

ELEVATIONS IN HUNDREDTHS OF FEET MTL.
CONTOUR INTERVAL 0.02

SCALE IN FEET
2 0 2 4 6 8 10

FIGURE 19
HYDROGRAPHIC SURVEY
TEST 5
AFTER 270 CYCLES OF OPERATION
WITH INLET

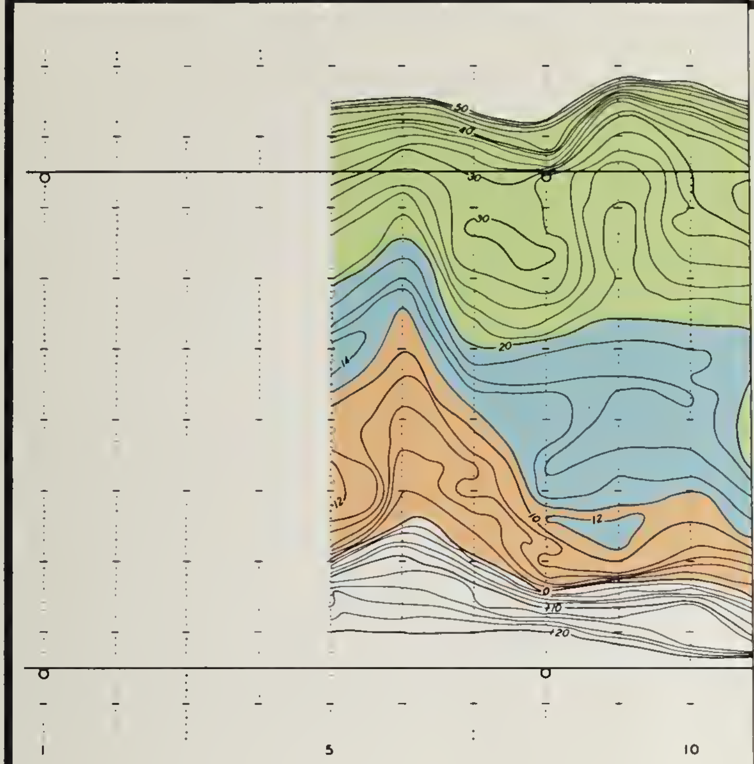


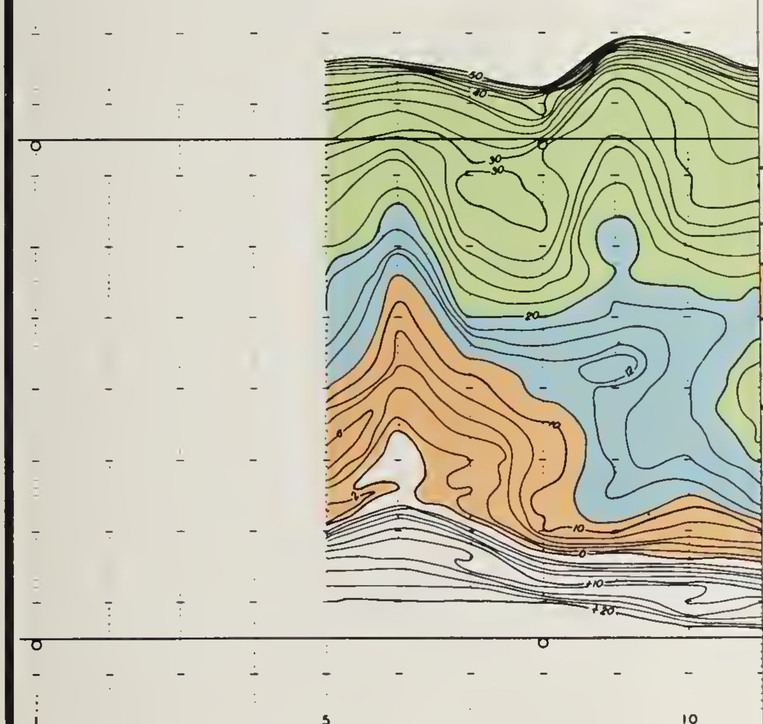
FIGURE 20

HYDROGRAPHIC SURVEY

TEST 5

TER 300 CYCLES OF OPERATION

WITH INLET



ABOVE 0 — -12 TO -20

0 TO - 12 — BELOW -20

VATIONS IN HUNDREDTHS OF FEET MTL.

NTOUR INTERVAL 0.02

SCALE IN FEET

2 0 2 4 6 8 10

FIGURE 21

HYDROGRAPHIC SURVEY

TEST 5

TER 330 CYCLES OF OPERATION

WITH INLET

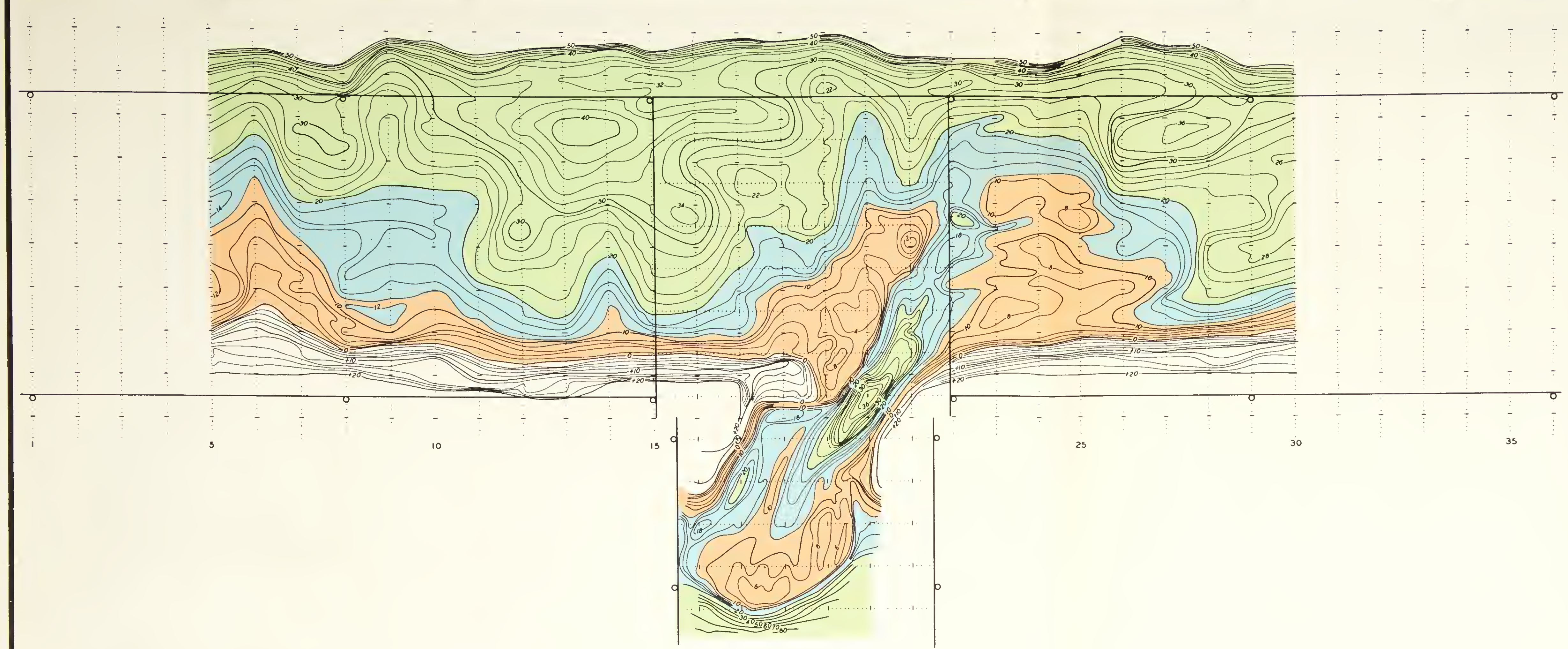


FIGURE 20
HYDROGRAPHIC SURVEY
TEST 5
AFTER 300 CYCLES OF OPERATION
WITH INLET

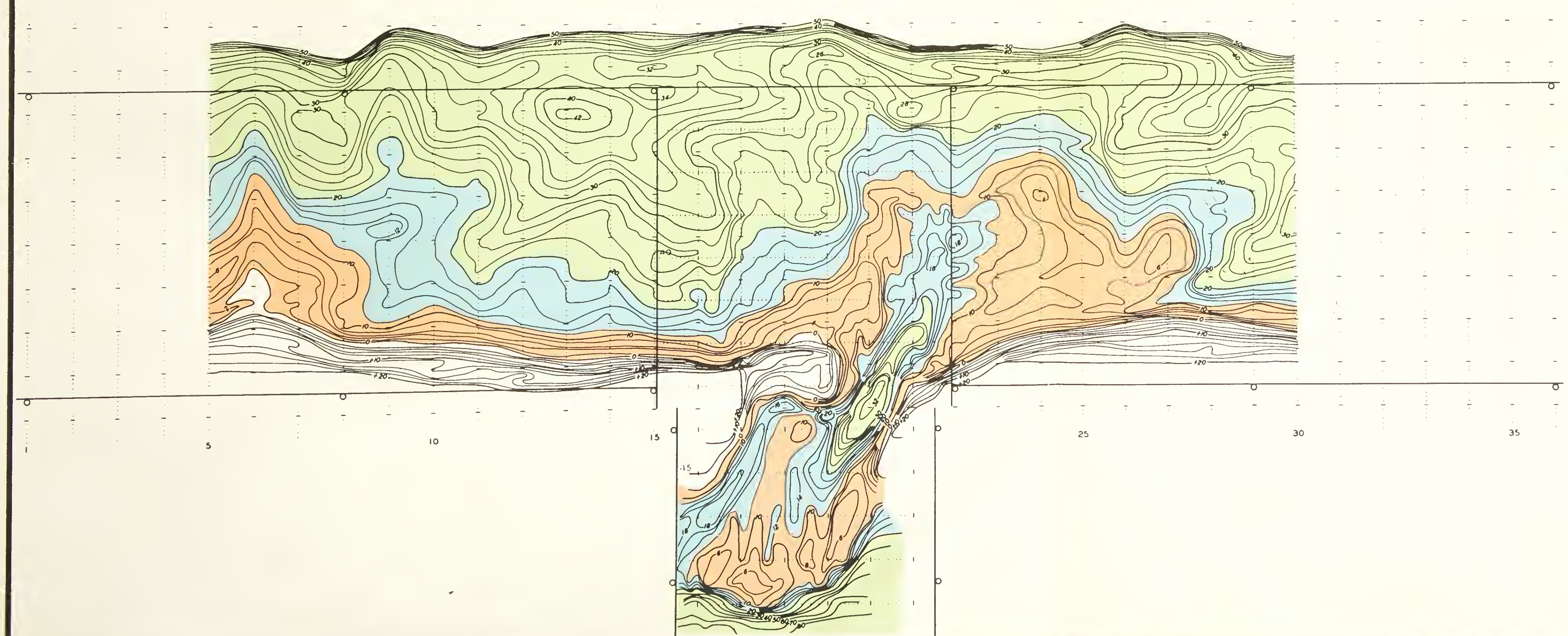


FIGURE 21
HYDROGRAPHIC SURVEY
TEST 5
AFTER 330 CYCLES OF OPERATION
WITH INLET

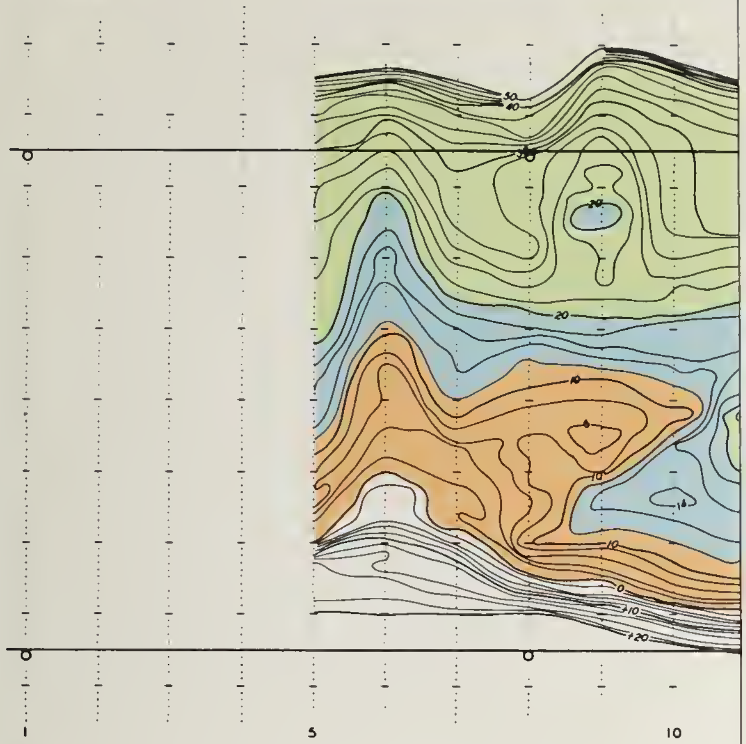


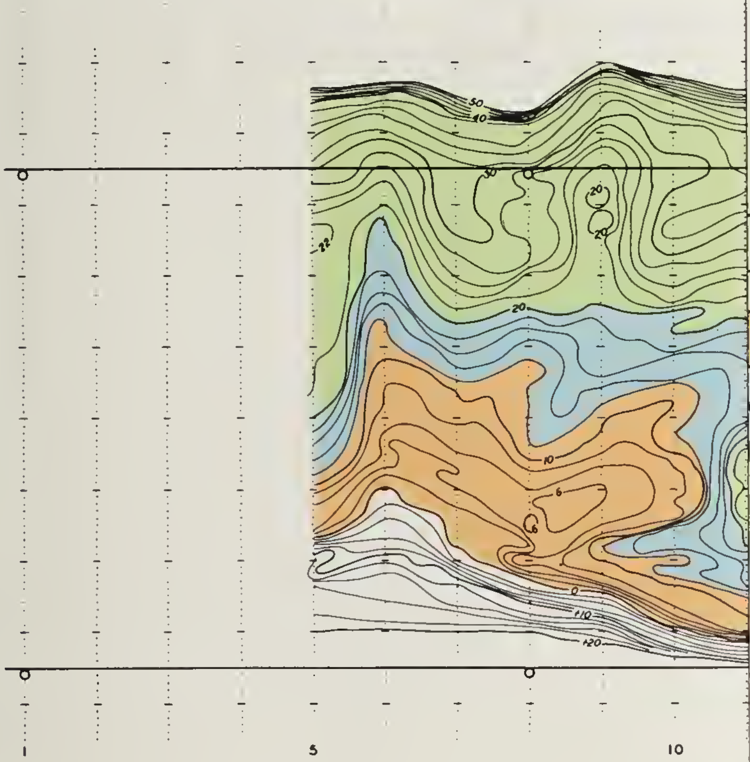
FIGURE 22

IYDROGRAPHIC SURVEY

TEST 5

ER 360 CYCLES OF OPERATION

WITH INLET



ABOVE 0	-12 TO -20
0 TO - 12	BELOW -20

VATIONS IN HUNDREDTHS OF FEET MTL.
TOUR INTERVAL 0.02

SCALE IN FEET
2 0 2 4 6 8 10

FIGURE 23

IYDROGRAPHIC SURVEY

TEST 5

ER 390 CYCLES OF OPERATION

WITH INLET

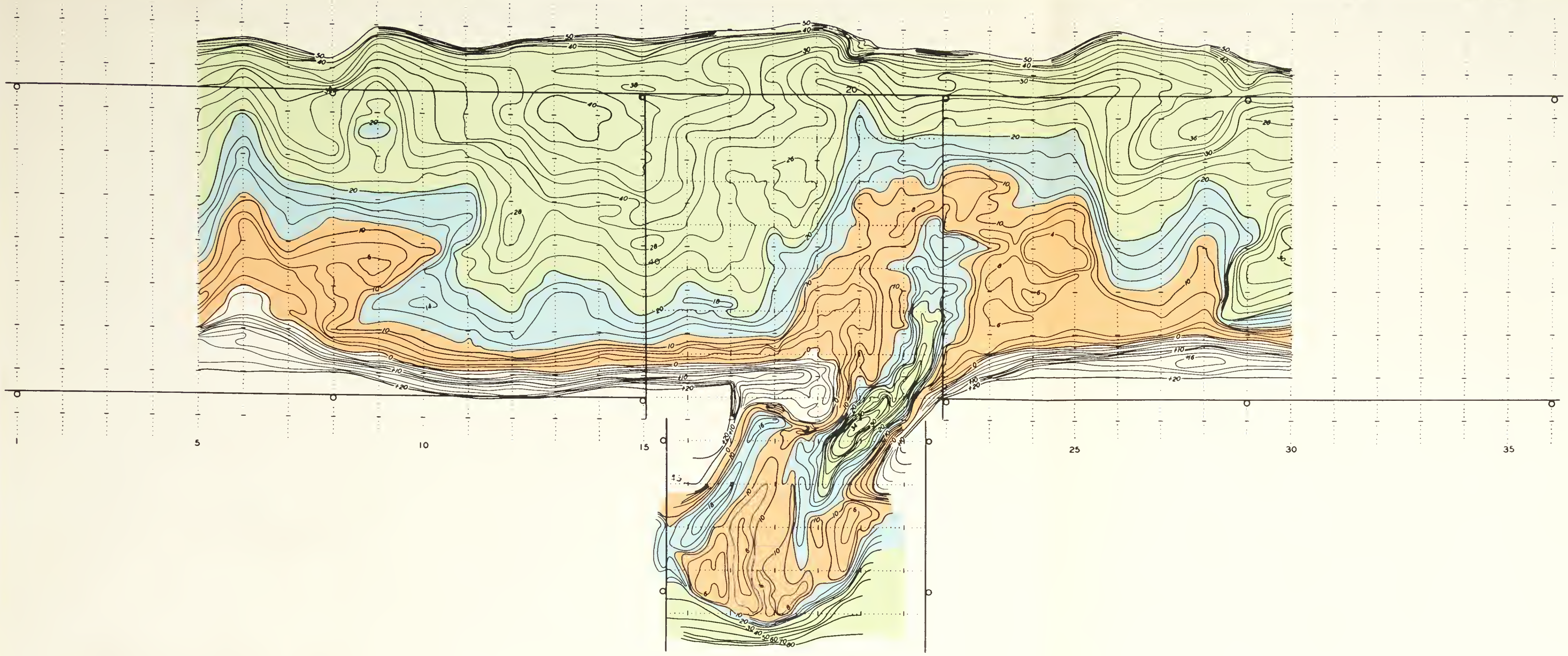
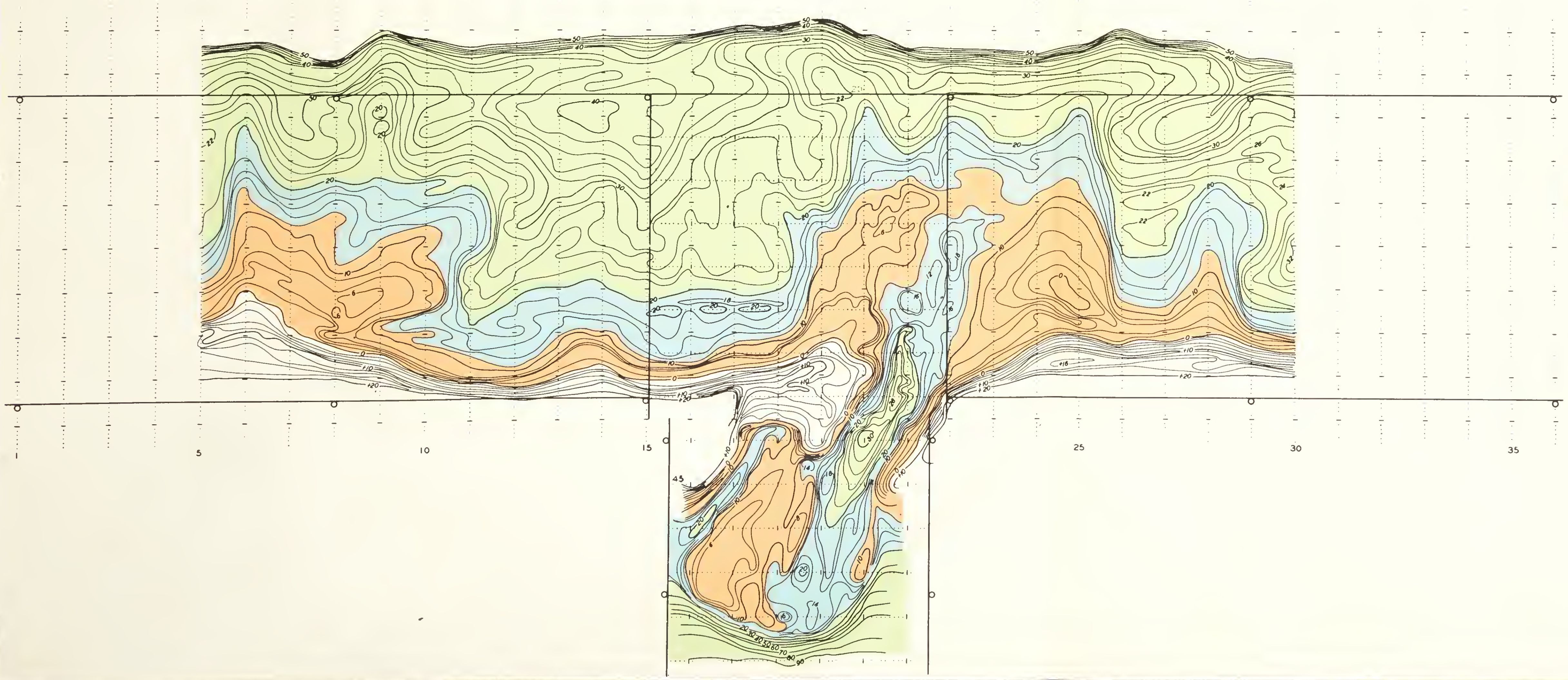


FIGURE 22
HYDROGRAPHIC SURVEY
TEST 5
AFTER 360 CYCLES OF OPERATION
WITH INLET



ABOVE 0

-12 TO -20

0 TO -12

BELOW -20

ELEVATIONS IN HUNDREDTHS OF FEET MTL.
CONTOUR INTERVAL 0.02

SCALE IN FEET
2 0 2 4 6 8 10

FIGURE 23
HYDROGRAPHIC SURVEY
TEST 5
AFTER 390 CYCLES OF OPERATION
WITH INLET

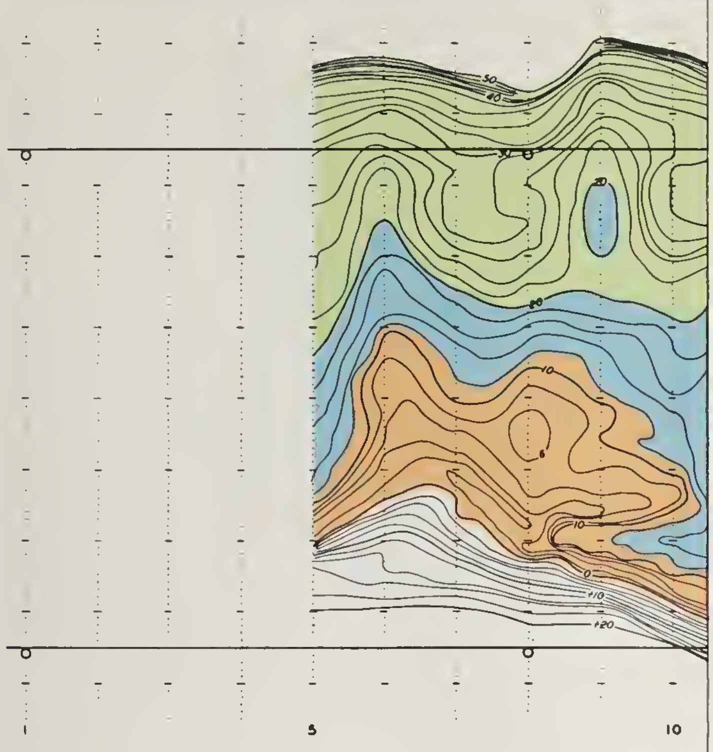
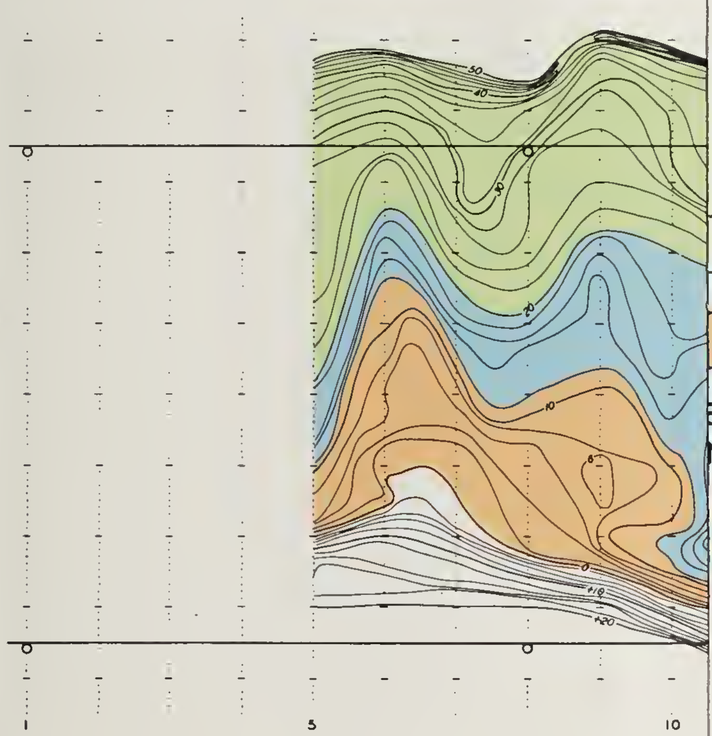


FIGURE 24

HYDROGRAPHIC SURVEY

TEST 5

TER 420 CYCLES OF OPERATION
WITH INLET



ABOVE 0 | -12 TO -20

0 TO -12 | BELOW -20

EVATIONS IN HUNDREDTHS OF FEET MTL.
NTOUR INTERVAL 0.02

SCALE IN FEET

2 0 2 4 6 8 10

FIGURE 25

HYDROGRAPHIC SURVEY

TEST 5

TER 450 CYCLES OF OPERATION
WITH INLET

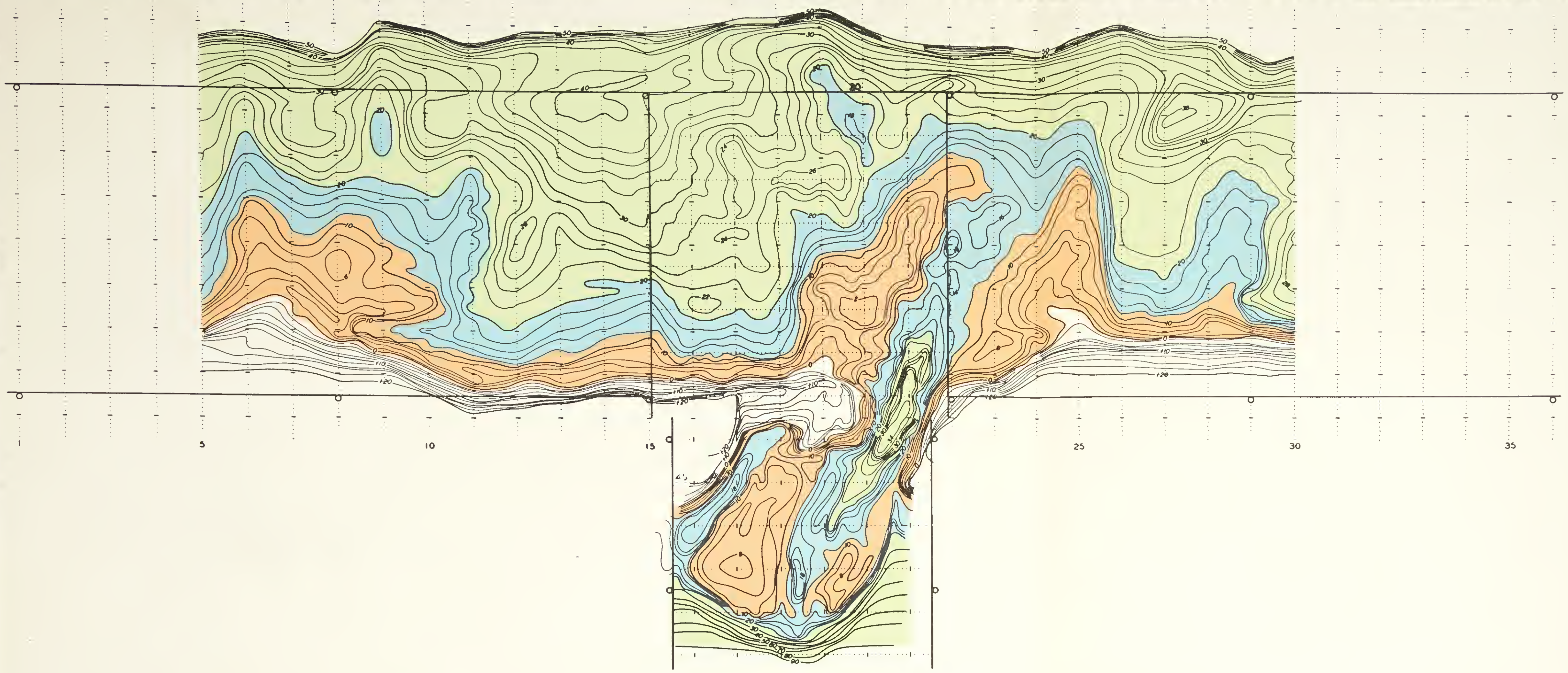
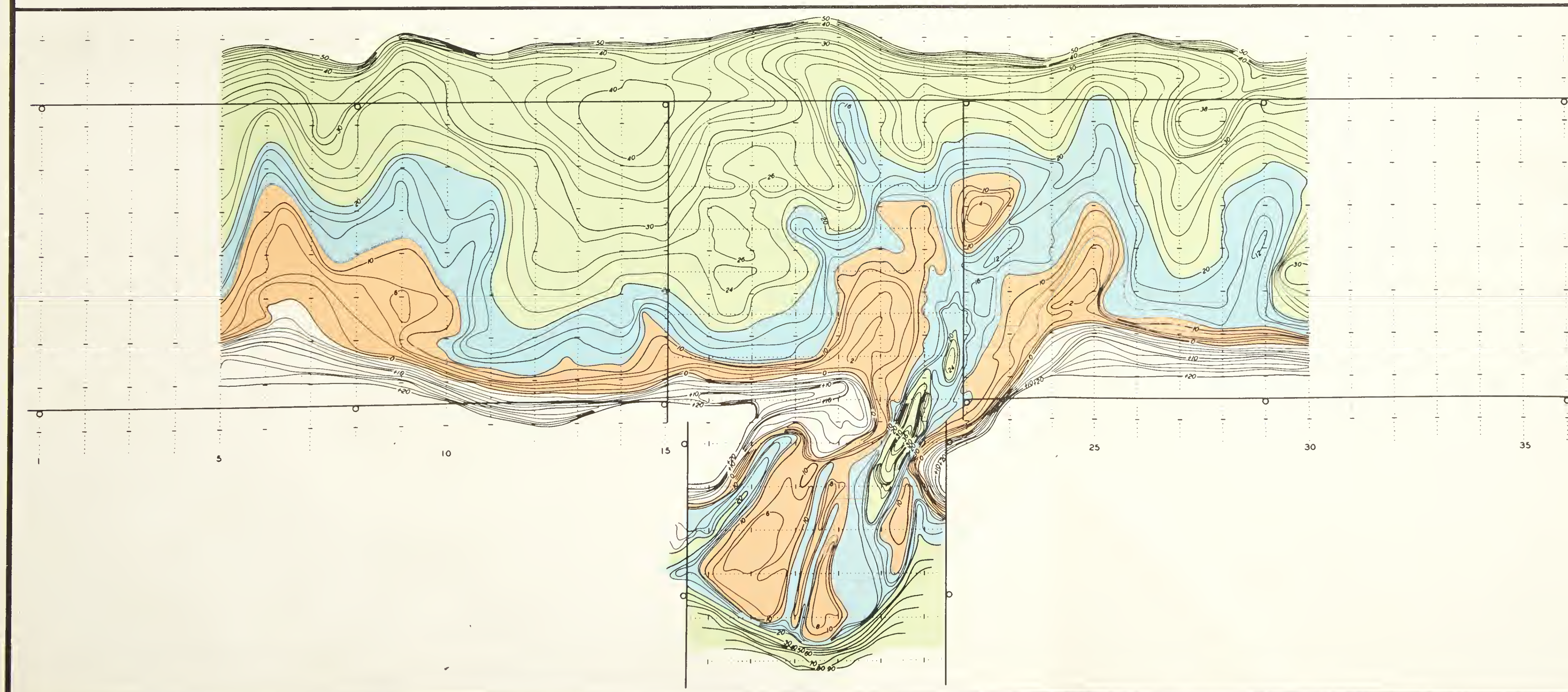


FIGURE 24
HYDROGRAPHIC SURVEY
TEST 5
AFTER 420 CYCLES OF OPERATION
WITH INLET



	ABOVE 0		-12 TO -20
	0 TO -12		BELOW -20

ELEVATIONS IN HUNDREDTHS OF FEET MTL.
CONTOUR INTERVAL 0.02

SCALE IN FEET
2 0 2 4 6 8 10

FIGURE 25
HYDROGRAPHIC SURVEY
TEST 5
AFTER 450 CYCLES OF OPERATION
WITH INLET

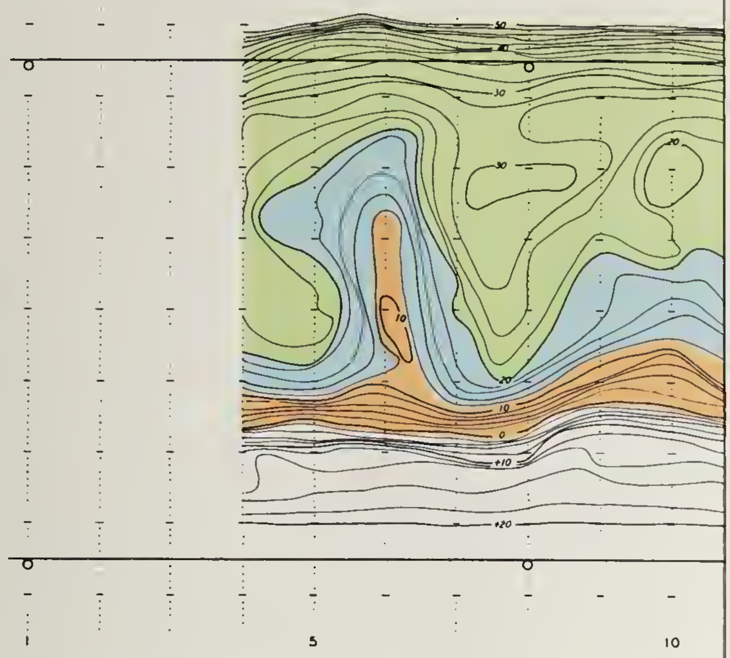


FIGURE 26
HYDROGRAPHIC SURVEY
TEST 6
INLET AS INITIALLY
T THROUGH STABILIZED BEACH

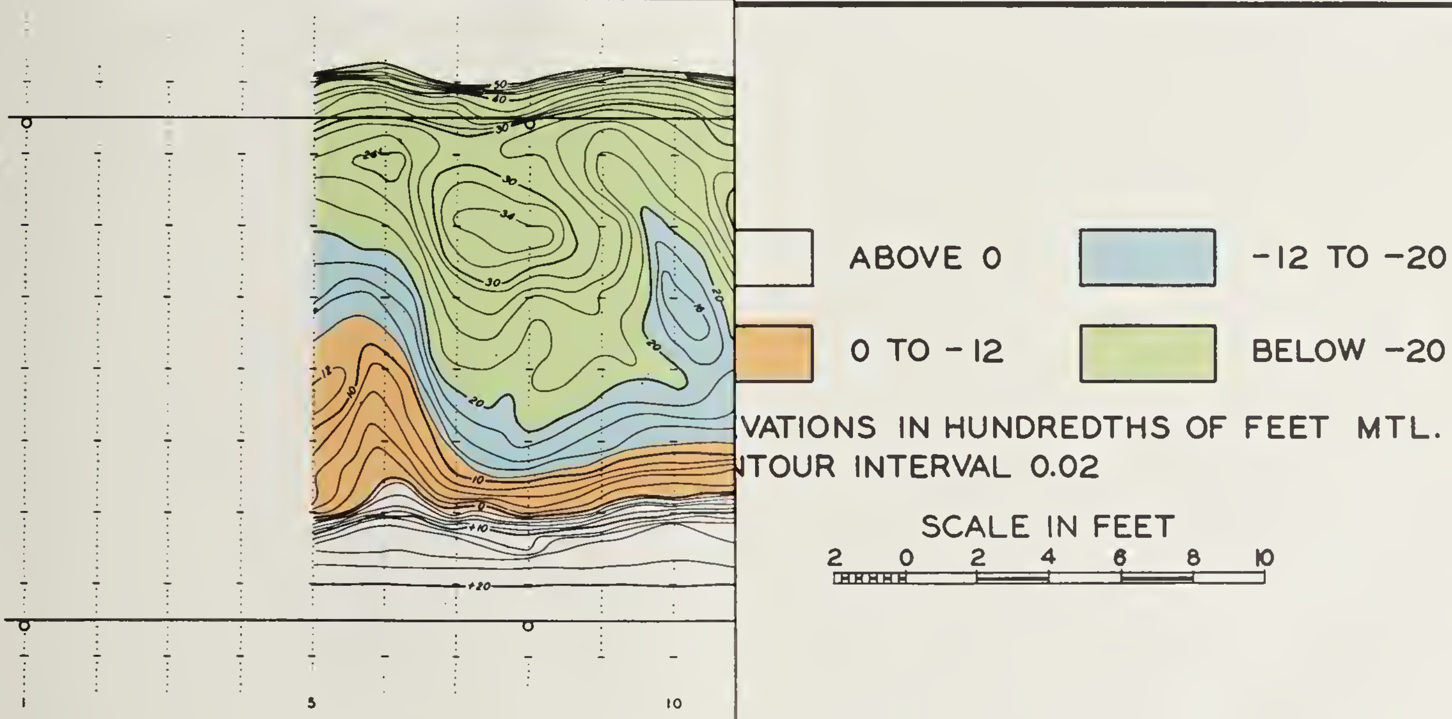


FIGURE 27
HYDROGRAPHIC SURVEY
TEST 6
TER 60 CYCLES OF OPERATION
WITH INLET

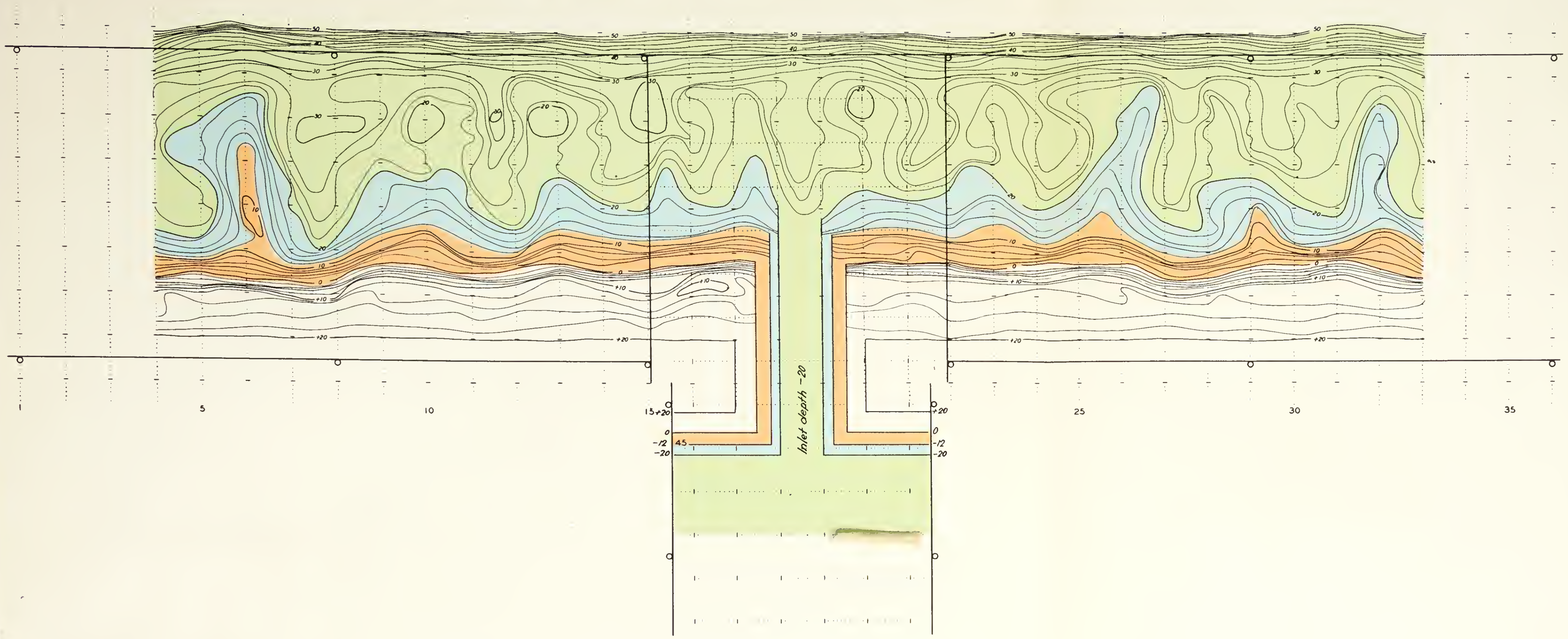
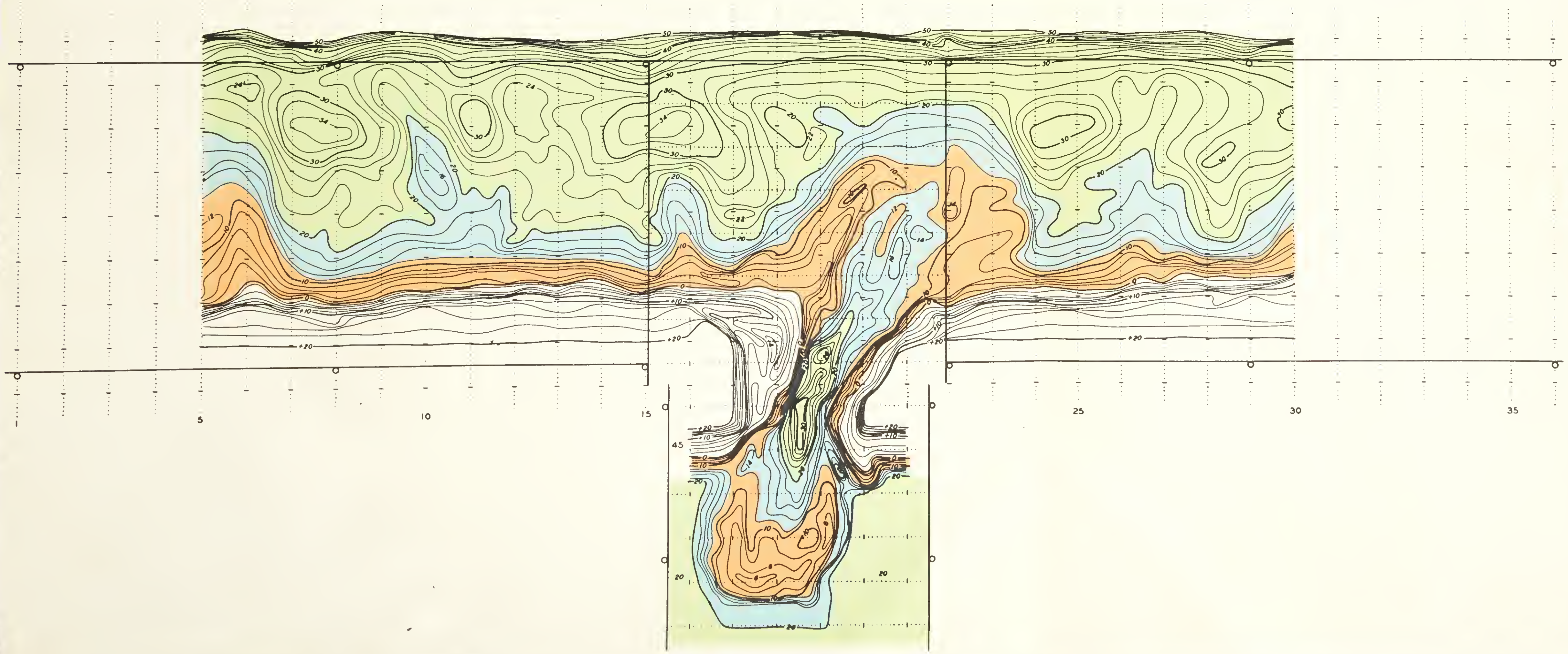


FIGURE 26
HYDROGRAPHIC SURVEY
TEST 6
INLET AS INITIALLY CUT THROUGH STABILIZED BEACH



	ABOVE 0		-12 TO -20
	0 TO -12		BELOW -20

ELEVATIONS IN HUNDREDTHS OF FEET MTL.
CONTOUR INTERVAL 0.02

SCALE IN FEET
2 0 2 4 6 8 10

FIGURE 27
HYDROGRAPHIC SURVEY
TEST 6
AFTER 60 CYCLES OF OPERATION WITH INLET

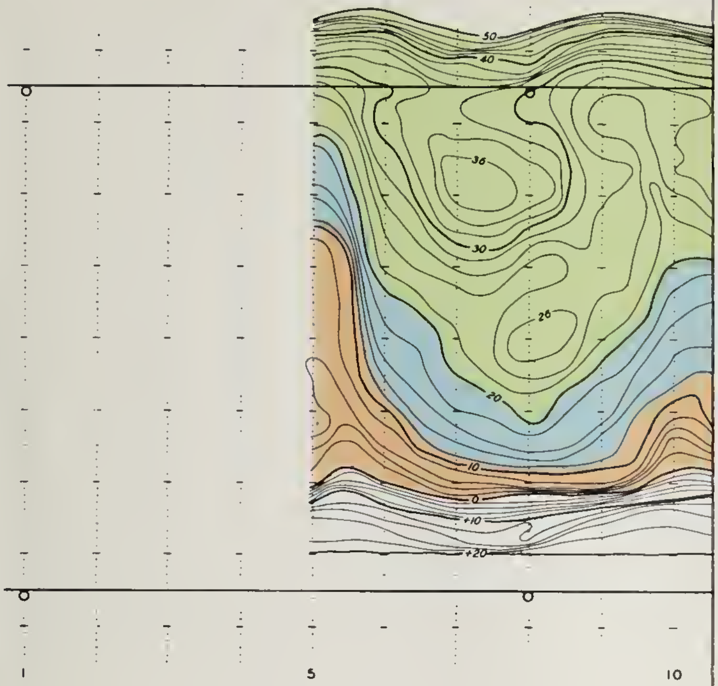
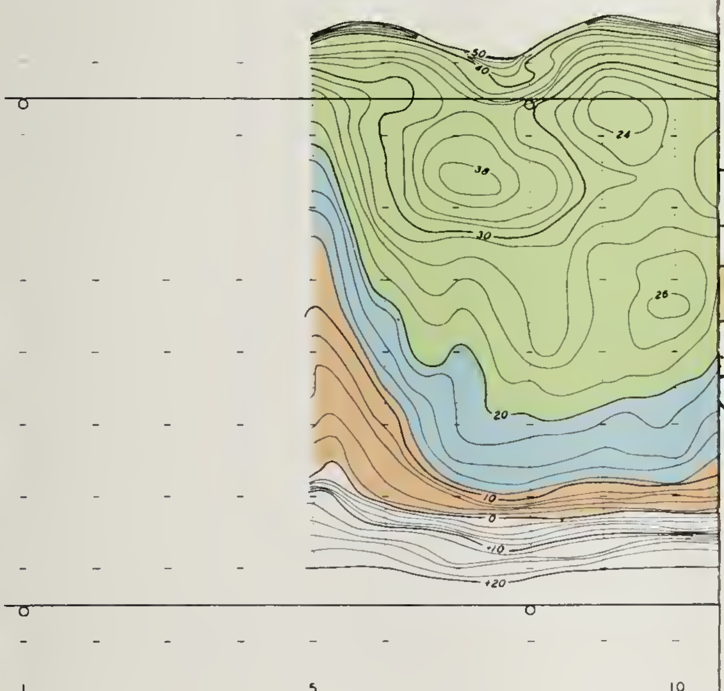


FIGURE 28
HYDROGRAPHIC SURVEY
TEST 6
TER 120 CYCLES OF OPERATION
WITH INLET



ABOVE 0
-12 TO -20
0 TO -12
BELOW -20

VATIONS IN HUNDREDTHS OF FEET MTL.
NTOUR INTERVAL 0.02

SCALE IN FEET
2 0 2 4 6 8 10

FIGURE 29
HYDROGRAPHIC SURVEY
TEST 6
TER 180 CYCLES OF OPERATION
WITH INLET

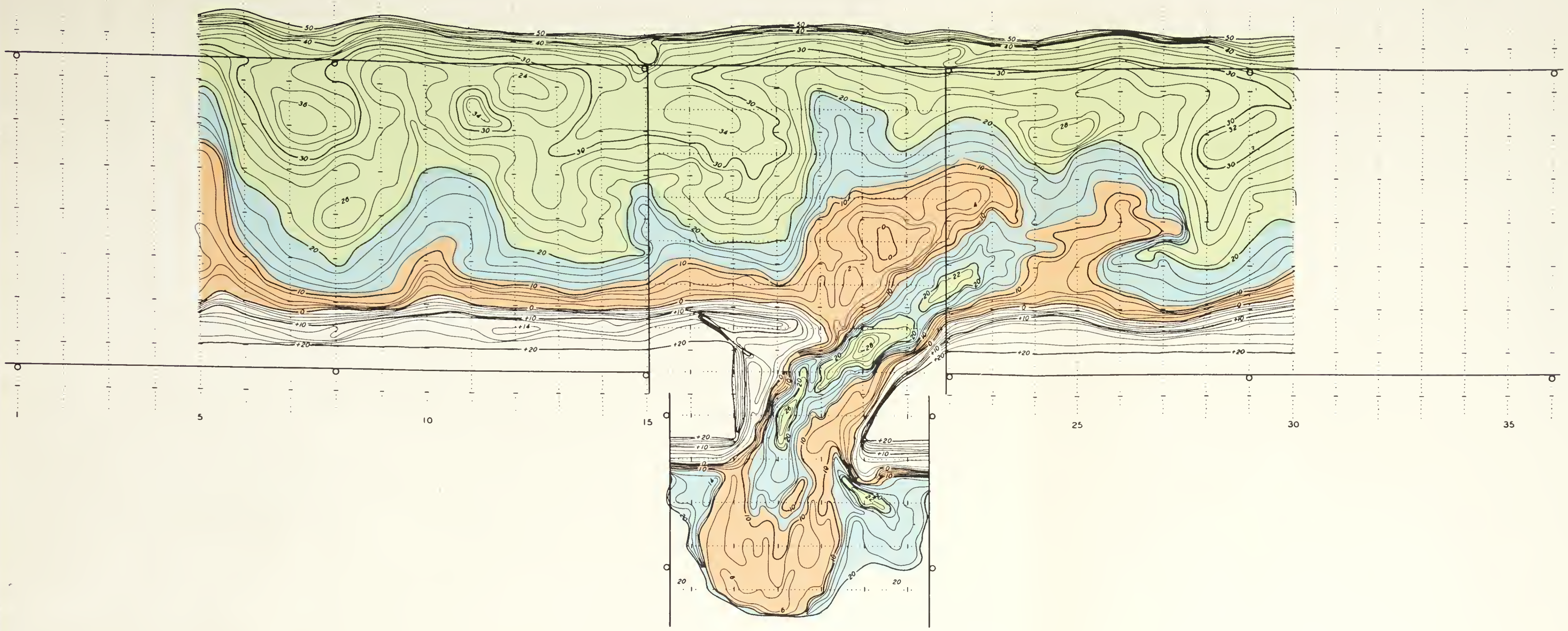
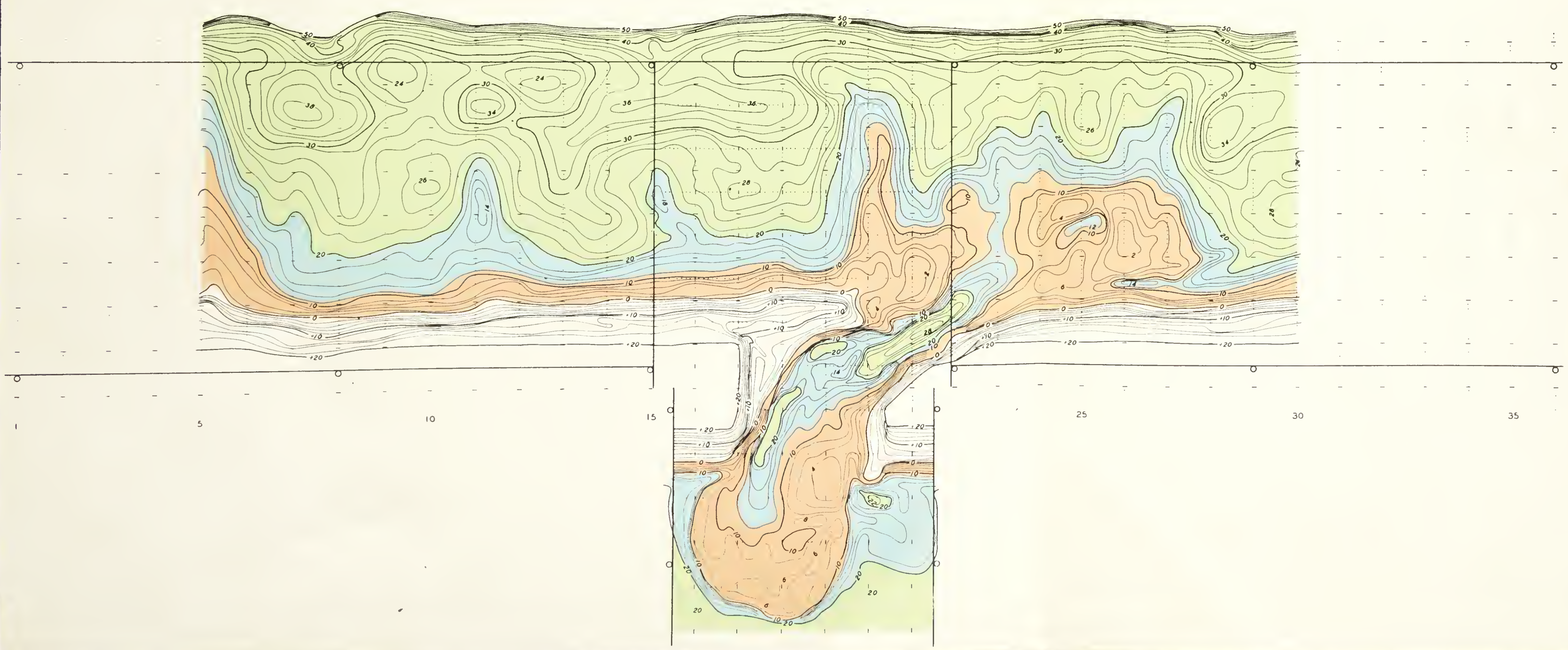


FIGURE 28
HYDROGRAPHIC SURVEY
TEST 6
AFTER 120 CYCLES OF OPERATION
WITH INLET



ABOVE 0 | -12 TO -20
0 TO -12 | BELOW -20

ELEVATIONS IN HUNDREDTHS OF FEET MTL.
CONTOUR INTERVAL 0.02

SCALE IN FEET
2 0 2 4 6 8 10

FIGURE 29
HYDROGRAPHIC SURVEY
TEST 6
AFTER 180 CYCLES OF OPERATION
WITH INLET

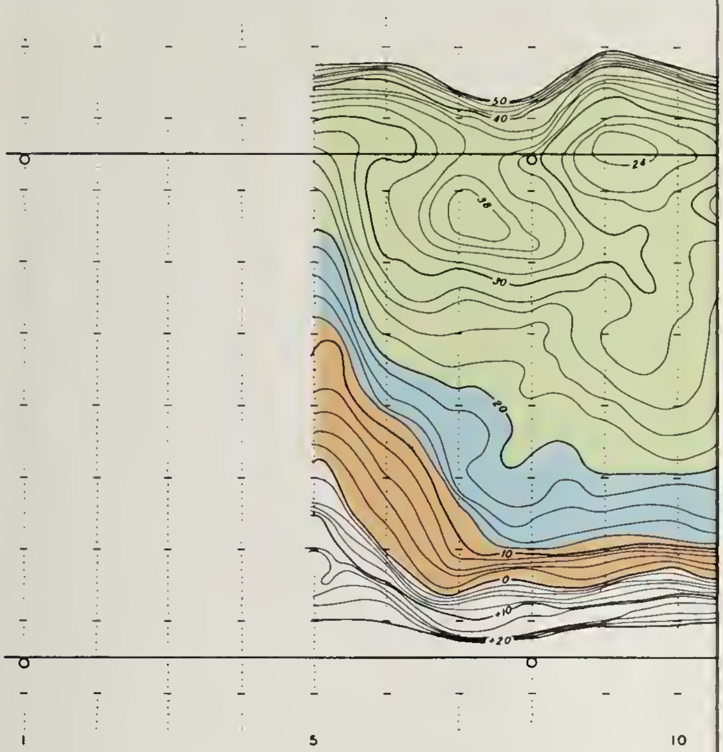
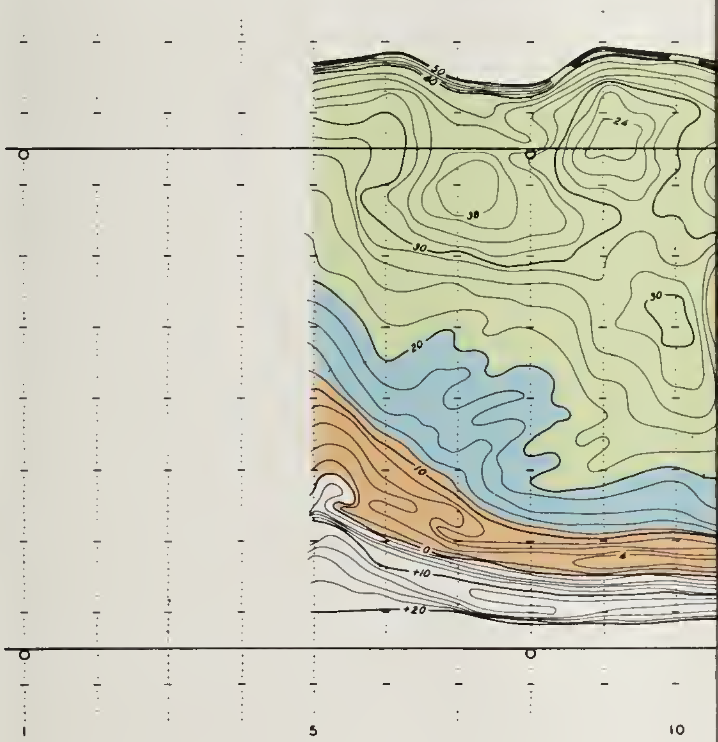


FIGURE 30
HYDROGRAPHIC SURVEY
TEST 6
TER 240 CYCLES OF OPERATION
WITH INLET



ABOVE 0 | -12 TO -20

0 TO -12 | BELOW -20

EVATIONS IN HUNDREDTHS OF FEET MTL.
NTOUR INTERVAL 0.02

SCALE IN FEET
2 0 2 4 6 8 10

FIGURE 31
HYDROGRAPHIC SURVEY
TEST 6
TER 300 CYCLES OF OPERATION
WITH INLET

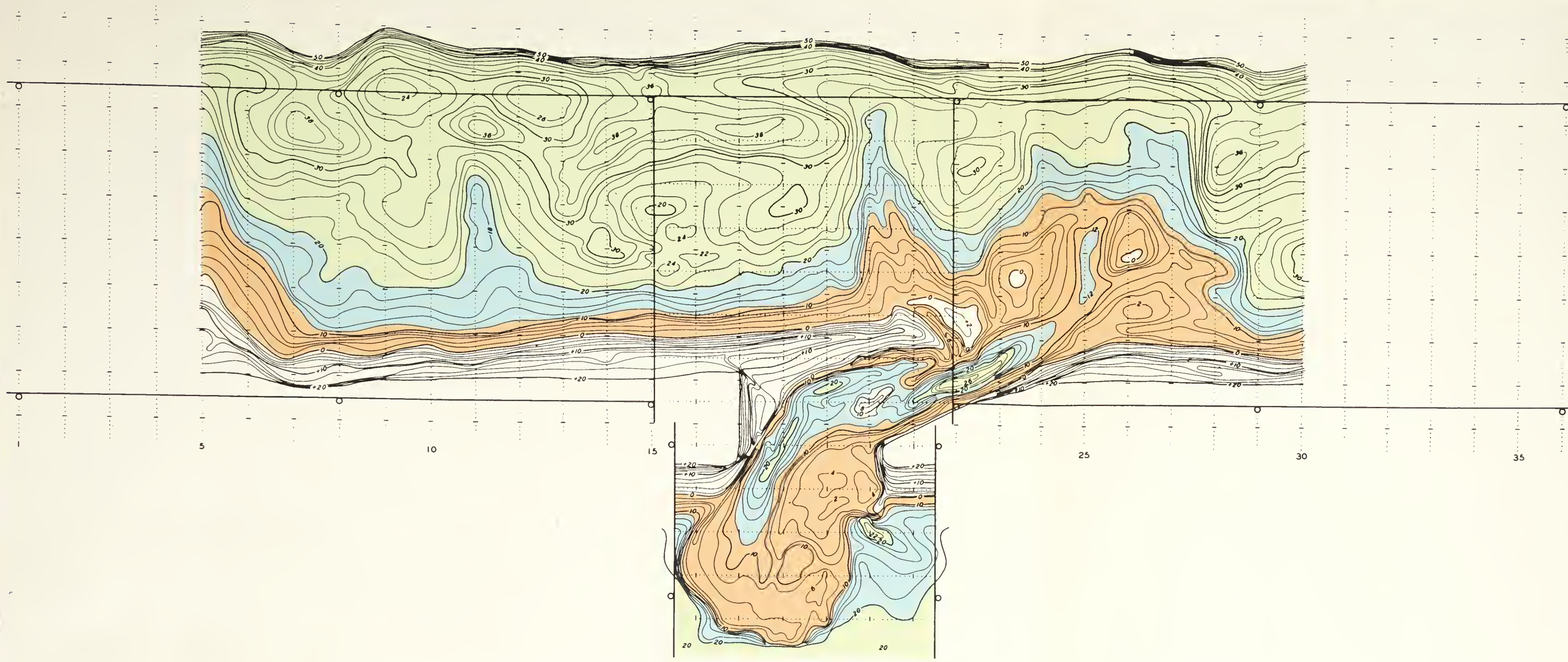
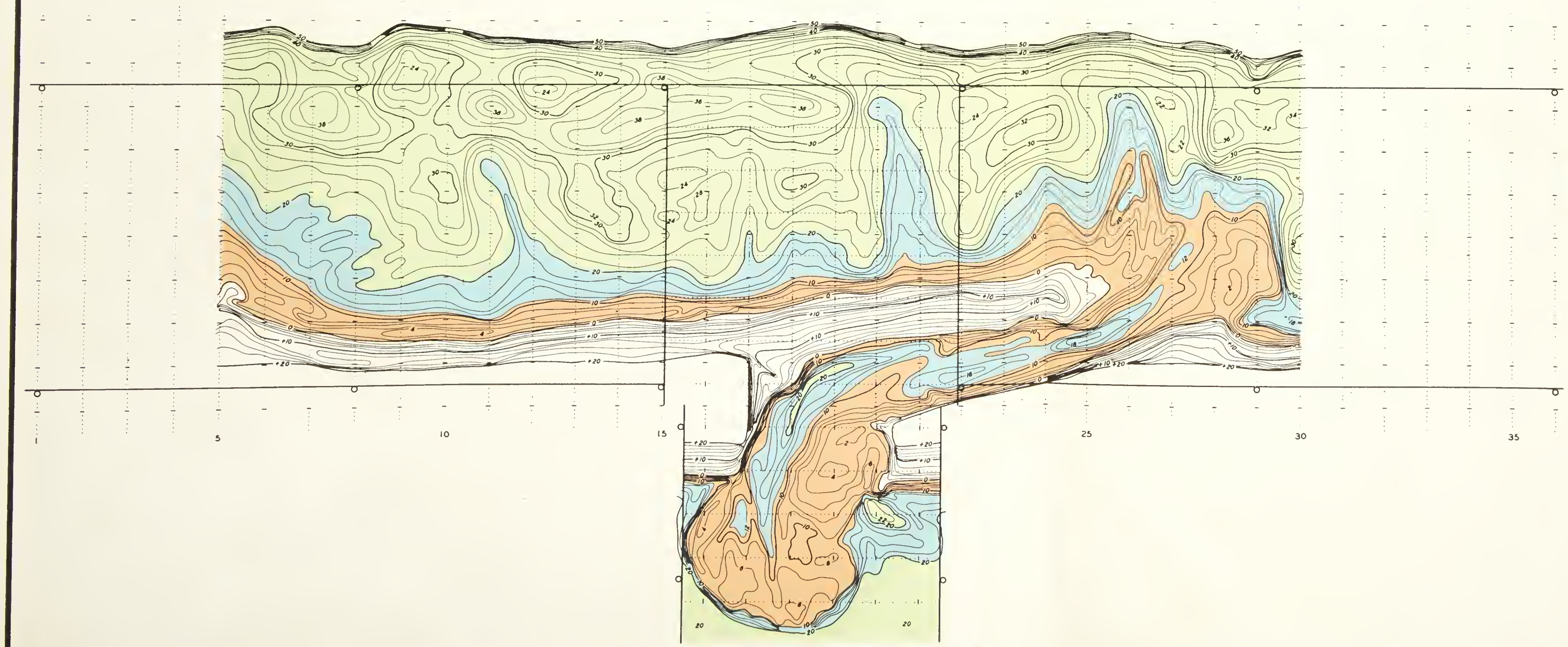


FIGURE 30
HYDROGRAPHIC SURVEY
TEST 6
AFTER 240 CYCLES OF OPERATION
WITH INLET



ABOVE 0
-12 TO -20
0 TO -12
BELOW -20

ELEVATIONS IN HUNDREDTHS OF FEET MTL.
CONTOUR INTERVAL 0.02

SCALE IN FEET
2 0 2 4 6 8 10

FIGURE 31
HYDROGRAPHIC SURVEY
TEST 6
AFTER 300 CYCLES OF OPERATION
WITH INLET

ABOVE 0

-12 TO -20

0 TO -12

BELOW -20

VATIONS IN HUNDREDTHS OF FEET MTL.
NTOUR INTERVAL 0.02

SCALE IN FEET

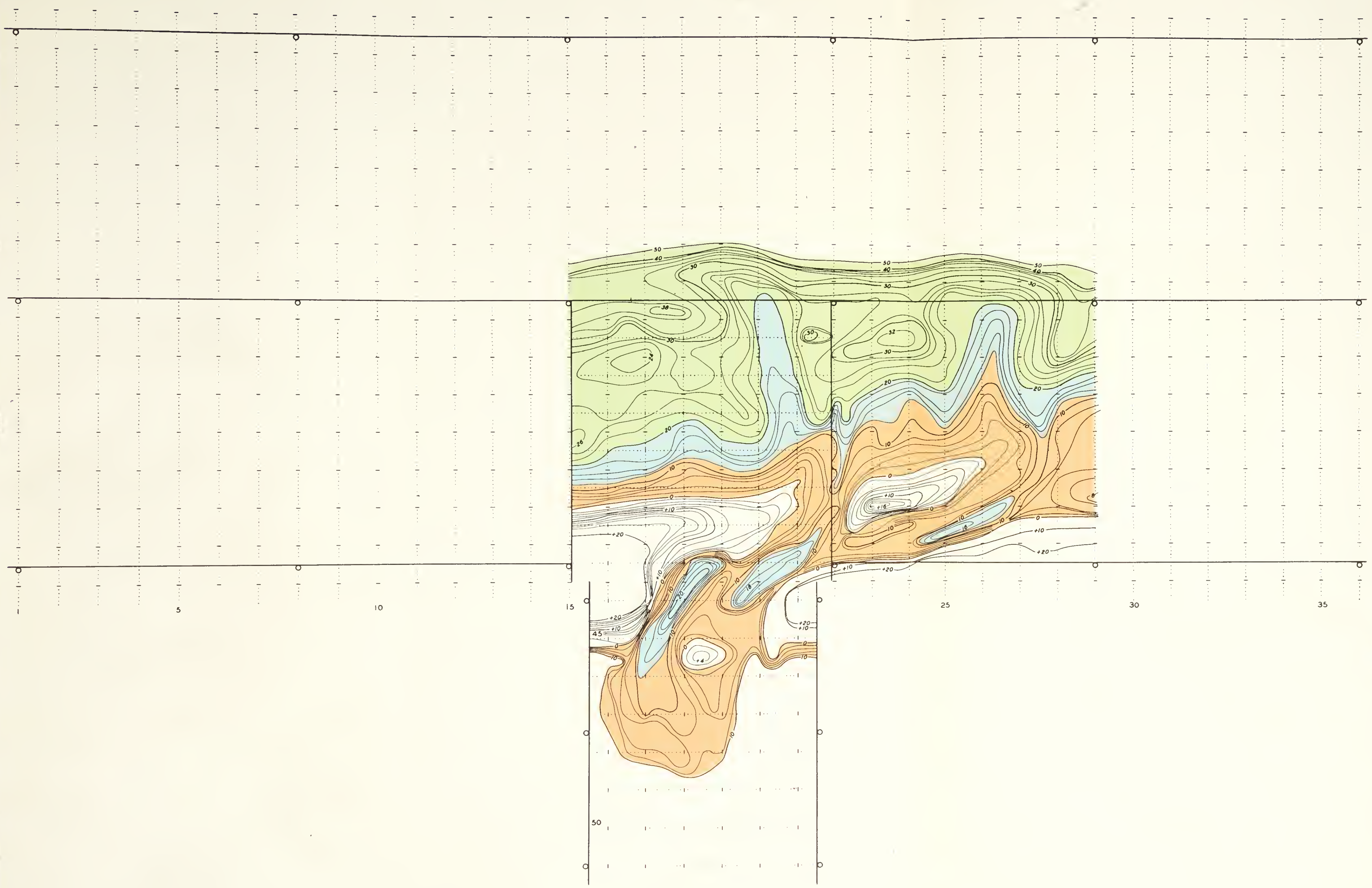
2 0 2 4 6 8 10

FIGURE 32

YDROGRAPHIC SURVEY

TEST 6

ER 310 CYCLES OF OPERATION
WITH INLET
M TIDES DURING CYCLES 301-310)



	ABOVE 0		-12 TO -20
	0 TO -12		BELOW -20

ELEVATIONS IN HUNDREDTHS OF FEET MTL.
CONTOUR INTERVAL 0.02

SCALE IN FEET
2 0 2 4 6 8 10

FIGURE 32
HYDROGRAPHIC SURVEY
TEST 6
AFTER 310 CYCLES OF OPERATION
WITH INLET
(STORM TIDES DURING CYCLES 301-310)